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Preface

The research documented in the report addresses the ground commander's needs for close fire support. It employs a series of high-resolution models and applies them in a variety of combat scenarios. It draws implications about the amount, type, responsiveness, and desirable characteristics of close support.

This study's findings will be of greatest interest to analysts concerned with the employment of ground forces in single-service or joint operations.

This research was conducted for the Office of Program, Analysis, and Evaluation in the Department of Defense. The work was carried out in the Acquisition and Technology Policy Center of RAND's National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Commands, and the defense agencies.

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Summary

Background

Ever since WWII, the importance of close support—defined as responsive, flexible fire support that is needed near enough to friendly forces that it requires detailed integration and coordination—has been well understood by ground commanders. Typically, fixed-wing aircraft, artillery, and, since Viet Nam, helicopters provide that support. Much of the analysis of close support needs has been done with a Cold War scenario in mind, where the threat, weather, and terrain were relatively constant. Only the variables of mobilization and warning time, strategic deployment, and the use of nuclear weapons were explored routinely.

But as Desert Storm and other operations since the end of the Cold War have made clear, the demands on U.S. forces have changed, and defense needs have changed along with them. The focus has shifted from the North German plain and the Fulda Gap to Haiti, Rwanda, Somalia, and Bosnia. Thus, defense planners no longer have a single scenario against which to plan, and they might reasonably ask if the need for close support has changed along with the much richer variety of scenarios U.S. forces must now contemplate. Indeed, some have even argued that the need for close support has all but disappeared in light of the U.S. ability to shape the close battle through interdiction.

An analysis of the operations conducted since the end of the Cold War suggests other common characteristics in addition to a change of venue. Most obviously, U.S. forces must adopt a contingency focus. Furthermore, they can anticipate working with a range of allies. Although recent operations have shown a willingness on the part of the U.S. to commit its forces to a wide range of operations in many locations, they also reveal an expectation that the U.S. will neither sustain many casualties in carrying out these operations nor cause many among the civilians who may be caught up in conflicts. Finally, these recent operations reflect a change in national interests and thus goals, making peacekeeping and peacemaking primary objectives.

Purpose and Approach of This Study

This study attempts to determine whether the ground commander's needs for close support have changed and, if so, the unique characteristics of the systems that can meet these different needs. To do so, the study team identified four categories of battlefield situations in which close support could be critical. These four situations address most of

the types of operations the U.S. is likely to carry out in the new national security environment. Not explored were operations similar to those of the Cold War, since abundant analysis exists on these sorts of engagements. The four categories examined here are as follows:

- Augmenting allies or other partners
- Supporting light infantry
- Handling "leading edge" problems (i.e., the problems faced by the first U.S. troops deployed in a major conflict when the enemy has the initiative and probably a substantial numerical advantage)
- Supporting offensive operations (these differ from the typical Cold War scenario in that the United States has seized the initiative and is on the attack)

To explore the issues associated with these four situations, researchers developed a series of detailed combat vignettes. These vignettes were run on a high-resolution combat simulation.[1] The focus was on determining how much additional support would be needed in the form of fixed-wing aircraft, helicopters, or advanced artillery to ensure a successful outcome. The seven vignettes developed and the combat situations they represent appear in Figure S.1.

Augmenting Allies
- Escort of a Humanitarian Convoy
- Support for an Allied Enclave

Supporting Light Infantry
- Small Unit Infantry Assault
- Small Unit Infantry Patrol

"Leading Edge" Problems
- Hasty Defense by Light Forces
- Prepared Defense by Light Forces

Supporting Mechanized Offensive Operations
- Armored Force Meeting Engagement

Figure S.1—Critical Combat Situations and Supporting Vignettes

[1]The simulation consists of a networked system of databases, analytic tools, and models, including JANUS (a ground combat model), CAGIS (a cartographic system), and BLUE MAX and CHAMP (flight path simulations for fixed- and rotary-wing aircraft).

Study Results for Critical Combat Situations

Each vignette had different criteria for success. Each assessment took into account the point at which the unit would no longer be able to continue its mission. For example, in escorting a humanitarian convoy, success was equated with minimizing friendly casualties. In other cases, it was equal to accomplishing a specific mission. Each vignette started with a base case in which no close support was used. Following the base case run, each vignette explored different levels of effectiveness for the ground force to determine if a more capable ground force might obviate the need for close support. The analysis then determined if close support could affect the outcome, and, if so, what means of close support produced the best results. Below is a summary of the study results for each of the seven vignettes, all of which typify critical combat situations in the new defense environment.

Escort of a Humanitarian Convoy

This vignette envisions a 40-vehicle convoy being ambushed by 24 attackers armed with a range of light infantry weapons. In the base case scenario (i.e., no close support), about half of the convoy vehicles are destroyed, and the attackers suffer only two casualties. Changing the scenario by replacing the high-mobility multipurpose wheeled vehicles (HMMWVs) with Bradley fighting vehicles does not change things much, except that more attackers get killed. Because the casualties occur so quickly in an ambush, even the most responsive close support does not preclude substantial losses to the convoy.

Two key observations emerge from the analysis. First, do not get ambushed. Once an ambush is sprung, substantial convoy losses are virtually inevitable. No close support asset is responsive or lethal enough to preclude significant losses. This finding suggests that better intelligence assets are needed to locate ambushes before they occur, e.g., a radar that could locate small arms. Second, retribution may act as a deterrent. Retribution can not be indiscriminate; therefore, some way of marking or tagging individuals involved in an ambush might be desirable.

Support for an Allied Enclave

This vignette depicts an allied enclave on the edge of a city defended by a small friendly force equipped with tube-launched, optically tracked, wire command linked (TOW) missile launchers mounted on HMMWVs. Allies contribute a light infantry company to the defense. The enclave is attacked by three battalions of heavy and medium armored vehicles supported by light and medium cannon artillery. Researchers determined that losing no more than 25 percent of the defending force would constitute success. In the

base case, only about half of the defenders survive, and they kill about half of the attacking force.

Providing effective close support changes the situation, limiting friendly losses and eventually destroying most of the attacking force. Key observations that emerge from this analysis include the following. First, using advanced artillery in this situation faces a number of challenges. Urban environments limit the number of locations in which to place artillery systems, and these would be easy for an adversary to identify in advance. The artillery itself is a lucrative target for counterbattery fire. Second, good battlefield information can improve the performance of both the organic and close support systems markedly. Good information enables the ground commander to position his systems to the best effect. It also enhances the synergy between the organic and close support systems. Third, to succeed, close support aircraft, fixed-wing or helicopter, have to kill enemy vehicles at a high rate. Given the confined airspace around the enclave, the close support assets have to kill multiple enemy vehicles on each pass. Finally, a better match between the shape of the target and the effects pattern of the munitions would improve the results of fixed-wing aircraft. The sensor-fuzed weapons (SFWs) used in the simulation have a long but narrow effects pattern, which has the most effect when the target has the same geometry. When the target has a different pattern, the effectiveness of the munitions falls off rapidly. However, munitions with terminally guided submunitions that are not as sensitive to target geometry kill substantially more armored vehicles. While these munitions cost more, their increased effectiveness seems to warrant the added cost.

Small Unit Infantry Assault

In this vignette, a platoon-sized Special Operations assault force has the task of neutralizing a high-priority apparatus located inside a military complex surrounded by guard towers. To be successful, the assault team has to get inside the complex, breach the storage facility, and destroy the apparatus without losing more than 25 percent of the force. The facility is defended by a 32-person security element, a 36-person immediate reaction force (IRF), and a company-sized quick reaction force (QRF) located nearby.

The base case results are a disaster: None of the assault team survives long enough to penetrate the storage facility. The fire delivered from the guard towers is devastating. When close support is brought to bear on the towers, the survivability of the assault team soars, and when it is applied to both the towers and the IRF, the results come very close to satisfying the criterion for success.

The main analytic lesson from this vignette is that the operation can not succeed without close support but that the type of support matters. One close support system analyzed was a conceptual NLOS/EFOG-M (non-line of sight/enhanced fiber-optic-guided

missile). It could not destroy the towers fast enough, so a mix of close support systems was needed. Combinations of F-117s with laser guided bombs (LGBs), EFOG-M, helicopters with Hellfire missiles, and 60-mm mortars all produced about the same results. However, destruction of IRF barracks always required a fixed-wing aircraft.

Small Unit Infantry Patrol

This vignette features a platoon-sized infantry patrol in a city in the Balkans. Returning from a routine patrol, the unit is ambushed by 51 irregular infantry occupying multi-story buildings along the patrol's return route. The kill zone for the ambush is a street flanked by 10-story buildings. Success is determined by the number of friendly infantry that survive the ambush.

In the base case, no one survives. About 12 members of the ambush are killed, but enemy casualties are not the measure of success. If some of the buildings could be neutralized (along with the enemy infantry in them), the patrol's chances of surviving would improve. However, no close support systems can deliver the needed capability in time to affect the outcome. As with the ambush described above, events move very fast, and springing the ambush is tantamount to enemy success. Again, the goal would be to avoid the ambush altogether. A second lesson is that responsiveness of a close support system is crucial. The engagement lasts two minutes. Support that arrives after that may exact casualties on the enemy force, but it will not affect the outcome for the friendly force. The analysis suggests that only helicopters flying over the patrol can be responsive enough to react in time. However, even though helicopters can be responsive enough, that does not mean that they can be effective enough to influence the outcome. The target location problem (infantry hiding in buildings) is severe. As with the earlier ambush, discriminative retribution may deter ambushes, but identifying and tracking those of the enemy that participate in ambushes is difficult.

Hasty Defense by Light Forces

The strategic mobility of airborne, air mobile, or marine forces makes them the ones most likely to be committed as the initial, or "leading edge," part of a response to an aggressor. The vignette modeled in the simulation pits elements of an airborne brigade against a two-regiment attacking force. The friendly force is largely light infantry, but it has about 40 vehicle-mounted anti-tank weapons, 10 light armored vehicles, and 6 Apache helicopters. The enemy has about 275 armored vehicles and supporting artillery.

Success for the friendly force hinges on its ability to destroy enemy vehicles at a distance while retaining 60 percent of its forces. To survive, the friendly force needs to destroy about 25 percent of the attackers. In the base case, the friendly force loses almost all of its

fighting vehicles and its helicopters. The enemy sustains heavy casualties but succeeds in capturing its objective, a critical road junction. Close support helps, but not enough. Even with close support, the friendly force still suffers too many casualties and does not kill enough enemy to meet its criterion for success.

Several points emerge from the analysis of this vignette. Close support by itself may not be adequate to offset the large disparity between the attacker and the defender. To hold out against armored forces, light forces need support that can deliver a high rate of fire and kill clusters of vehicles. They also require long-range and survivable target acquisition systems that enable them to engage the enemy before being engaged themselves. Responsive fires are necessary to compensate for a lack of tactical mobility.

Alternatives to solving this problem need to be considered. Some of the analysis suggests that more capable ground forces in concert with close support might be able to handle this very demanding situation. Other alternatives should also be considered, e.g., interdicting the enemy before he is able to close with the friendly force and bring his overwhelming direct and indirect fire assets to bear.

Prepared Defense by Light Forces

This case features a light infantry brigade defending a critical road junction in Southwest Asia against an advancing enemy armor division. The brigade has three battalions of light infantry, 58 vehicle-mounted anti-tank systems, and 14 light armored vehicles. The enemy force has just over 500 armored vehicles.

Success for the friendly force is defined as retaining 60 percent of its force while inflicting 40 percent casualties on the enemy. That level of losses will preclude the enemy from continuing his mission to seize the road junction. The base case results are much more favorable for the friendly unit than in the hasty defense, underscoring the importance of prepared positions. Slightly less than half the friendly force survives, and only 45 percent of the attacker. The friendly force inflicts sufficient casualties on the enemy to meet the criterion for success but does not retain enough of its own forces. Effective close support both increases the number of enemy casualties and enhances the survivability of the friendly unit because fewer enemy are available to inflict damage.

Some of the analytic lessons mirror those of earlier vignettes. Matching munitions effects patterns with target arrays enhances munitions effectiveness. More capable munitions can help resolve some of the target location difficulties. One insight is that ongoing efforts to develop more effective artillery munitions, such as SADARM (sense and destroy armor) and BAT (brilliant anti-tank) do not appear to answer the close support needs as well as terminally guided sub-munitions concepts do. Adaptive targeting, e.g., provided by unmanned aerial vehicles (UAVs) in orbit over the battle, was also shown to

increase effectiveness. Further, it is clear that the close support systems have to match the strategic mobility of the light forces. The strategic mobility of the light units is the primary reason why they would be employed in this situation, and their close support systems must be able to accompany them. One insight here is that current artillery systems require more lift than helicopters do, and helicopters take more lift than fixed-wing aircraft do. However, when advanced smart munitions are added to the equation, all systems require significantly less lift (two to 10 times less), with the artillery benefiting the most.

Armored Force Meeting Engagement

This vignette has a reinforced brigade-sized unit encountering an enemy force of similar size. Both units engage from a march formation, with the enemy assuming a hasty defense, and friendly units launching a hasty attack. The success criterion for the friendly force is to destroy three-quarters of the enemy force while retaining 70 percent of its own force. The base case results show that about 30 percent of each force survives. Thus, the friendly force meets its criterion for neither lethality nor survivability. Actual close support systems improve both areas for the friendly force, but not enough to constitute success. In part, this results because the systems are limited to a close support role; that is, they are not permitted to interdict the enemy force. However, that limitation reflects real-world conditions when the enemy's intentions are not known until the first shots are fired.

Analysis of the vignette results reveals the following points. First, the effectiveness of the SFWs modeled in the simulation was limited by the fact that the enemy forces dug in and limited the ability of the aircraft to match the effects pattern of the weapon (long and narrow) with the linear array of the target vehicles. Trading the SFWs for Maverick missiles only makes things worse in terms of aircraft attrition. In the main, the fixed-wing munitions could not be brought to bear before the enemy stopped and dug his vehicles in, thus largely negating the advantages of the munitions. On the other hand, the advanced artillery systems were effective. The targets were stationary, and the high angle of attack of EFOG-M and the Damocles launched by the multiple-launch rocket system (MLRS) took away the advantage of being dug in. Finally, the analysis indicates that serving the right target at the right time confers a premium. The use of UAVs to provide targets for the artillery enabled those systems to attack the most lucrative target sets.

Overall Implications

Looking across the analytic results for all the vignettes, we draw a number of conclusions. We discuss these first by describing the conclusions with respect to how

much close support is needed, against what kinds of targets, and with what degree of responsiveness. We then turn to the types of characteristics needed by close support systems to answer the needs. However, one of the lessons of this analysis is that not all needs relate directly to weapons systems. Munitions and information needs claim equal priority, so we offer some insights in these areas as well.

How Much Close Support Is Needed?

- **Ground forces need additional firepower in many situations.** In some cases, more effective ground units could provide the needed firepower. However, in other cases and in a broader range of cases, close support was necessary to achieve success. Typically, the results suggest that the close support assets kill enough enemy systems, but not always the right ones to ensure that enough friendly systems survive to achieve success.
- **In several plausible situations, the ground commander's need for close support exceeds future capabilities.** In these cases, a successful outcome requires a combination of enhanced ground force capability and close support. Alternatively, it might be more practical to shape the battlefield by attacking road nets or interdicting enemy forces before they can close with friendly light units. However, in some cases—ambushes—no technical solution seems feasible. In these cases, detecting the ambushes and avoiding them offers the best solution.
- **The need to avoid ambushes is important in the new defense environment.** It has always been important to avoid ambushes. However, in the new defense environment, activities such as urban patrols and convoy escorts are increasingly likely and important. Ambushes are the most effective countertactic to these activities. So they, too, are more likely. Given the effectiveness they demonstrated in the simulations, avoiding them is the best option, since close support is neither responsive nor lethal enough to preclude friendly casualties.

Which Targets Need to Be Attacked?

- **Close support systems need to be able to deal with a mix of targets.** The range of vignettes shows that armored vehicles are not the only types of targets that U.S. forces will have to attack in the future. Some systems are better at attacking one type of target than another. Thus, a mix of systems will be required along with a range of missions.
- **Discriminative retribution may deter ambushes.** Avoiding ambushes is the preferred strategy. However, analysis suggests that it might be possible to find and kill the ambushing force after the ambush. This strategy is not recommended, since

indiscriminate retribution can have negative effects. But if those setting the ambushes had some reason to believe that they might not survive it, they might be deterred. Some research into target sensing and marking may prove beneficial.

- **Hitting the right target at the right time offers high payoff.** Although this is more of an information insight than a firepower one, it is nonetheless significant. Good targeting information, such as that provided by UAVs, enables friendly forces to attack the targets posing the greatest threat throughout the battle. This benefit is even greater than perfect information before the battle, which enables the force to attack high-value targets initially but not continuously.

How Much Responsiveness Is Needed?

- **Responsiveness is not simply a matter of time.** In one sense, response time is a false metric. It does not matter how fast the response occurs if it does not affect the outcome, as was the case with the ambushes. A more relevant measure might be kills per minute. Analysis across the vignettes indicates that the kill rate of current systems is inadequate to shift the results of a battle from the negative to the positive. Kill rate may have little to do with system responsiveness. Advanced artillery firing Damocles, which has a large footprint, was much more effective than artillery firing SADARM, which has a small footprint, but both arrive at the same time.

Desirable System Characteristics

One analytic finding of this research is that platforms—fixed-wing aircraft, helicopters—are not the only, or perhaps even the primary, focus. Munitions, sensors, and information are all important to how the battle ends. Thus, this section talks not only to platform characteristics but also to those of munitions, sensors, and information.

Fixed-Wing Aircraft. The strength of fixed-wing aircraft is that they can carry large weapons loads over long distances. However, the analysis in this study shows that they can not destroy armored vehicles fast enough except when carrying the most recent anti-armor cluster bombs. Thus, more sophisticated weapons would be useful, most particularly those that can acquire targets autonomously. Also desirable are the long-range target detection and recognition capabilities necessary for standoff delivery and "point-and-shoot" delivery. Development efforts also need to take account of the broader range of targets likely in the new defense environment.

Rotary-Wing Aircraft. These are survivable enough but lack the lethality necessary to tilt the balance of battles. Needed are faster target acquisition means and more rapid launch rates. Also important is a capability for helicopters to identify the air defense threat.

Finally, some low-observable additions would be useful, particularly when helicopters are used in support of operations by Special Operations Forces (SOFs).

Advanced Artillery. Artillery offers a number of advantages, particularly its ready availability in bad weather, darkness, etc. However, it is not very effective against armored targets, especially when they are moving. Thus, some investment in terminally guided sub-munitions (TGSMs) could raise the effectiveness of these systems. However, artillery systems would also benefit from work to enable them to attack a broader range of targets, e.g., point targets such as bunkers. To this end, systems based on fiber-optic guidance would be beneficial. Furthermore, some of the vignettes illustrate the need for a light mortar that soldiers can carry over rough terrain. Since the load they can carry is limited, munitions for this mortar need to be accurate and lethal enough to destroy point targets without requiring a large number of rounds.

Sensor and Targeting Systems. One of the more intriguing results of the analysis is that firepower questions can have an information-based answer. For example, the best strategy for avoiding an ambush is to avoid it. Thus, detecting and locating ambushes is the priority. If the threat can be located, the range of munitions and platforms available now can adequately deal with it. Another insight is that allocating fires can be as important as delivering them. The same number of kills could lead to victory or defeat, depending on how they were distributed. Information enables a better coordination of organic and close support assets. Adaptive targeting lets the ground commander attack the most lucrative targets as the battle situation changes.

Glossary, List of Symbols, etc.

AAA	Anti-Aircraft Artillery
AFV	Armored Fighting Vehicle
AGM	Air-to-Ground Missile
AGS	Armored Gun System
APC	Armored Personnel Carrier
ATACMS	Army Tactical Missile System
ATGM	Anti-Tank Guided Missile
BAI	Battlefield Air Interdiction
BAT	Brilliant Anti-Tank
BDA	Battle Damage Assessment
BM	Battle Management
C3I	Command, Control, Communications and Intelligence
C4I	Command, Control, Communications, Computing and Intelligence
CAP	Combat Air Patrol
CAS	Close Air Support
CBU	Cluster Bomb Unit
CEP	Circular Error Probable
CS	Close Support
DMA	Defense Mapping Agency
DMZ	Demilitarized Zone
DPICM	Dual Purpose Improved Conventional Munitions
DPRK	Democratic Peoples Republic of Korea
DRB	Division Ready Brigade
E(K)	Expected Kills
ECM	Electronic Countermeasures
EFOG-M	Enhanced Fiber-Optic Guided Missile
FIST	Fire Support Team

FLIR	Forward-Looking Infrared
FLOT	Forward Line of Troops
FOG-M	Fiber-Optic Guided Missile
FSR	Former Soviet Republic
GAU	Gun Aircraft Unit
GBU	Guided Bomb Unit
GCC	Ground Component Commander
GPS	Global Positioning System
HARM	High-Speed Anti-Radiation Missile
HMMWV	High Mobility Multi-Wheeled Vehicle
HUMINT	Human Intelligence
IFFN	Identify Friend, Foe or Neutral
IFV	Infantry Fighting Vehicle
IIR	Imaging Infrared
IR	Infrared
IRF	Immediate Reaction Force
IRTGSM	Infra-Red Terminally Guided Munitions
JDAM	Joint Direct Attack Munitions
JSTARS	Joint Surveillance Targeting and Reconnaissance System
LGB	Laser Guided Bomb
LRC	Lesser Regional Contingency
MLRS	Multiple Launch Rocket System
MMW	Millimeter Wave
MMWTGSM	Millimeter Wave Terminally Guided Munitions
MOE	Measures of Effectiveness
MRC	Major Regional Contingency
MSR	Main Supply Route
NATO	North Atlantic Treaty Organization
NFoV	Narrow Field of View
NLOS	Non-Line of Sight
NVEOL	Night Vision Electro-Optics Laboratory
ODS	Operation Desert Storm

OPEC	Organization of Petroleum Exporting Countries
Pa	Probability the A/C acquires the target
Pd	Probability the A/C killed in a single pass
PGMs	Precision Guided Munitions
Pk|d	Probability the A/C kills the target it detects
QRF	Quick Reaction Force
RCS	Radar Cross Section
ROE	Rules of Engagement
ROK	Republic of Korea
RPG	Rocket Propelled Grenade
SADARM	Sense and Destroy Armor
SAM	Surface-to-Air Missile
SEA	Southeast Asia
SEAD	Suppression of Enemy Air Defenses
SFW	Sensor Fused Weapon
SOF	Special Operations Forces
SSPK	Single Shot Probability of Kill
SWA	Southwest Asia
TACFIRE	Tactical Fire Control
TGSM	Terminally Guided Sub-Munitions
TMD	Tactical Munitions Dispenser
TOW	Tube Launched, Optically Tracked, Wire Command Linked
UAV	Unmanned Aerial Vehicle
WFoV	Wide Field of View

1. The Problem and Approach

The Problem

Objectives

Two important forces of change, one in technology (which determines capabilities) and another in the defense environment (which determines needs), are combining to change the systems and employment concepts used for close support. Taken together, these systems and employment concepts will shape the force structures of the future. But before that shaping can take place rationally, several key questions need to be answered. Two of these are

- How might the ground commander's needs for close support change in the future?
- What are the unique characteristics of systems that can meet these new needs?

This study tries to shed light on these two questions.

The Terms of the Analysis

Definitions are important to analysis. Frequently, discussions move at cross-purposes because participants ascribe different meaning to terms. We use *close support* to refer to firepower provided to a tactical ground commander by a supporting force that must be integrated or coordinated with the fire, movement, and other actions of the supported force. This supporting fire can be provided by a number of different weapons systems. In this study we generally consider three: fixed-wing aircraft, rotary-wing aircraft, and advanced artillery.

The Challenge: A New Defense Environment

In the past, most analysis was based on the Central European scenario that was generally well defined. Thus, the battlefield situations considered fell in a fairly narrow set of circumstances (defensive posture, terrain, weather, threat size, etc.) that remained fairly constant over four decades of analysis. As a result, the bulk of analytic explorations examined only variations in mobilization and warning times, strategic deployment, and the use or non-use of nuclear weapons when testing the central question of which system was most cost-effective.

With the fall of the Soviet Union and the disappearance of the Warsaw Pact, the issues facing defense analysts and planners have become more diverse. The U.S. Armed Forces are transitioning into a contingency force capable of supporting the nation's foreign policy

worldwide.[1] As a result, the needs for close support and the means of providing it may be changing as well. Additionally, the diverse experience of recent combat involvement (Operation Desert Storm, Operation Just Cause, and Operation Provide Hope) suggests a reappraisal of many of the previous findings in light of the nature of the contingency battlefield and new information on the effectiveness of various types of weapons systems. No longer does a single scenario shed sufficient light on security strategies, force structure requirements, employment considerations, or—as is the focus in this study—weapon system characteristics.

Prior studies, focused on defensive armored combat, have concluded that a mix of system characteristics—those provided by artillery, rotary-wing, and fixed-wing systems—would be the most cost-effective way to provide close support. Moreover, these studies found that many current systems are not effective enough to influence battle outcomes and thus require enhancement. Additionally, Operation Desert Storm experience argues that changes in technology may reduce the overall need for close support in conflicts involving mechanized warfare where the U.S. has the initiative. Analysis by Frostic (1993) and others strongly suggests the ability of the U.S. to control the battlefield by interdicting the movement of armored forces before they make close contact with friendly forces will shape the close battle.

If correctly interpreted, many of the insights these assessments have provided are likely to remain valid; however, the new defense environment has a decidedly different emphasis that may importantly color this interpretation. The key elements of this environment include

- A contingency focus that makes the scenario (place, timing, and situation) uncertain—or perhaps more correctly, unknowable.
- Involvement with a wide range of potential allies and pan-national organizations.
- The expectation of ultra-low attrition. Or perhaps more fundamentally, an appreciation of the less critical nature of the national interests involved in many potential conflicts and a willingness to risk only commensurably fewer losses.
- A need for the considered and precise use of force due to heightened concerns about collateral casualties and damage.
- National interests and mission objectives that are importantly different from decisive combat. Recognizing peacekeeping/peacemaking operations as a primary mission objective (instead of considering them to be a lesser-included case) changes many of the performance criteria we expect of systems and places greater demands on technical characteristics.

Before committing limited resources to solutions that may be strongly colored by the experience of the Cold War or the latest instance of contingency operations, decision-makers must be provided a broader analytic basis that accommodates the considerations noted above. This will

[1] Aspin(October 1993) outlines one of the first official statements of this transition.

allow them to evaluate alternatives and determine the proper direction of future research, development, and acquisition efforts.

Implications of Previous Research

Previous RAND research provides the following context for the current study:[2]

- There are three classes of systems—helicopters, artillery, fixed-wing aircraft—developed and operated by four services that can provide close support to a combatant commander. These have fundamental differences in capabilities and limitations that can not be ignored.
- Because of the different capabilities and limitations of close-support-capable systems and the different future battle situations that call for close support, the employment schemes that best support the joint commander in combat are a matter of right system, right place, and right time.
- These capabilities and limitations also dictate that cost-effective force structures are likely to be made of some mix of these different classes of systems.
- Changes in military technology (e.g., battlefield surveillance and targeting systems and effective anti-armor sub-munitions for artillery and aircraft) may be decreasing the need for close support in mechanized combat and may provide significant capability to meet those more limited needs.
- Analogous capabilities to find and engage forces at depth in light infantry combat have not progressed much beyond those of the Vietnam conflict (or World War II, for that matter), while the advent of man-portable surface-to-air defense systems argues that aircraft enjoy less latitude than in previous conflicts.
- Little progress has been made in developing a coherent and cost-effective approach to handling the fratricide problem (which may be exacerbated by the increases in sensor capabilities and munitions lethality) despite the promise of advanced navigation and information systems. What progress has been made has focused on mechanized combat.

An Approach to Assessing Future Needs and Desirable System Characteristics

To assess the future needs for close support we sought to define those battlefield situations in which close support might be critical to battle outcomes. We then used this appreciation of close support needs and the battle context from which they derived to determine what desirable characteristics future systems should have in order to provide this capability on the battlefield.

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[2]For a summary of this work, see Don, 1994.

To determine these critical battlefield situations, we reviewed evolving U.S. defense policy and strategy, analyzed recent U.S. military experiences, and developed and assessed a group of scenarios designed to be representative of future U.S. security issues. We then developed a set of high-resolution combat vignettes and analyzed them using a suite of detailed combat simulations. To determine desirable system characteristics, we conducted further analysis using these combat vignettes and employing high-resolution models of alternative close support systems.

Determining Close Support Needs by Defining Battlefield Situations Where Close Support May Be Critical

As outlined above, this analytic process started by determining future close support needs. This required that we first understand what challenges the new defense environment might present for U.S. forces.

Estimates of the challenges presented by the future battlefield situations that are typical of this new defense environment must not only incorporate the emerging lessons from recent combat experience, but must also reflect the current orientation on contingency operations, the strong emphasis on working with regional allies in these contingencies, the need to operate with very low loss rates, and the uncertainty associated with the new defense environment.

It could be argued that Operation Desert Storm experience indicates that future close support needs are well in hand for mechanized warfare where the U.S. has the initiative because of its ability to control the battlefield and shape the terms of the close battle. Given that this is the form of warfare the U.S. would like to impose on an adversary and that U.S. planning seeks to incorporate this advantage, it has been asserted that there is little need for close support on the future battlefield. However, other plausible (and perhaps most likely) circumstances promise to be less comfortable. These include

- The farsighted adversary that the U.S. feared would materialize (but did not) to attack its "leading edge" forces in the Gulf War.
- Vietnam-like conflicts, especially those so close to U.S. borders and national interests that they were impossible to ignore.
- U.S. experience in Panama and Somalia, particularly in the urban environments experienced in those conflicts.
- The unfolding situation in the Balkans.

The types of situations noted above bespeak the uncertainty as to time, place, and type of warfare inherent in contingency operations.

Our analytic approach to dealing with this uncertainty has been to regard a prudently wide set of possible future combat situations to ensure we have the broadest grasp possible of what future needs for close support may be. To do this, we reviewed U.S. guidance and long-range planning

documents to ascertain the kinds of military challenges inherent in the evolving U.S. national military strategy, and we analyzed recent U.S. foreign military involvement. Additionally, we conducted an assessment of possible future scenarios, relying on a group of experienced defense analysts from a range of backgrounds.

Analyzing the Defense Guidance and Planning Documents

To understand the impact of the changes in the defense environment, our study team reviewed the various documents that define the defense policy and military strategy of the U.S. (for example, Aspin, September 1993; Powell, 1992 and 1993). This review established that future U.S. military involvement overseas would most assuredly involve coalition warfare. Additionally, numerous situations will exist in which U.S. forces could be called upon to provide close support to allied and other coalition forces (such as United Nations peacekeeping forces) that are deficient in these capabilities.

The situations in which the U.S. may provide support to allies and other coalition forces appear to be characterized by a wide range of constraints that arise because of differences in doctrine, communications, training, equipment, or experience in working with U.S. forces. Further, differences in allied ground force capabilities (lack of adequate combat power) and approach to the conflict (excessive aggressiveness or hesitancy) may invite or force close battle with the enemy, thus increasing the need for close support beyond what the U.S. would plan for if supporting only U.S. ground forces.

A Critical Battlefield Situation: Supporting Allied Forces

This suggests that one of the important categories of battle situations, in which close support might prove critical to the battle outcomes, is supporting allied and other coalition forces. This finding was confirmed by our review of recent U.S. combat experience, including that in Operation Desert Storm and Somalia, and the current involvement in Bosnia; later it will be shown to be supported by our analysis of future contingencies with which the U.S. might be faced.

The need for the U.S. to provide close support to its allies was found to be contingent upon whether the U.S. had the initiative in a military operation. If the U.S. was at a disadvantage—as it might be during the initial phases of a contingency—and was limited to a defensive operation, the adversary might choose to challenge a weakened allied force in order to rupture the coalition defense. The increased weight of enemy effort in allied sectors would heighten the need for close support in those areas.

In examining U.S. defense planning and guidance and the doctrine supporting the military strategy they define, it became apparent that, since Vietnam, U.S. military doctrine has moved to a fighting concept that calls for the engagement of enemy forces long before they come in contact with U.S. forces, thus reducing the need for close support.[3] The technology that the U.S. has

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[3]For a history of this change, see Romjue, 1984.

already used in combat (such as JSTARS, anti-armor sub-munitions, and attack helicopters) has shown that it is practical to engage the enemy well before the U.S. is committed to close battle—for mechanized combat.

However, for other conflicts—those where U.S. forces were confronted by a light infantry adversary like those that would be most appropriate for the combat environment of urban settings, rugged, broken terrain, and forest or jungle battlefields—it became apparent that the U.S. is much less capable of actuating such a doctrine even though it would be preferable to close combat.

The anti-personnel capability of air and artillery munitions has long been far more effective than their anti-armor capability. If only considering the lethality of systems, an apt framing of the current developments might be that anti-armor capability is finally catching up with the anti-personnel capability. Current munitions (including new cluster bombs and mine delivery systems) are very effective against infantry that have been located accurately, if the troops are not immersed in a neutral populace or town. This was typically the case during the major-unit infantry battles experienced in World War II, Korea, and Vietnam and is one of the reasons that artillery has been the leading cause of infantry casualties on the battlefield for many decades. However, an important additional consideration is the current inability to locate and target light infantry deployed in rugged or jungle terrain and the U.S. hesitancy to use saturation bombing or artillery fires because of collateral damage considerations. These have largely precluded an ability to "shape" the close battle and have limited the ability to support units engaged in close battle as well as the U.S. might like once combat is joined. This suggested a focus for our review of recent U.S. military operations.

Reviewing Recent U.S. Military Experiences

The study team reviewed recent U.S. contingency operations and military involvement to understand the types of combat and critical battlefield situations that may challenge U.S. forces in the new defense environment. This review also informed our choice and development of the combat vignettes that were used in the study as the basis for our detailed simulation analysis. Figure 1.1 details the U.S. contingency operations we considered.

A common characteristic found in many of these operations is a dependence on "light infantry forces" due to their appropriateness to the situation and terrain or due to their ability to be quickly deployed to the theater of conflict. These forces often require close support to offset two key limitations that are inherent in light infantry: (1) a limitation in the firepower that they can carry and (2) constraints on their tactical mobility deriving from their need to travel on foot in most situations (e.g., urban, jungle terrain, or air insertion) once they have been emplaced.

OPERATION NAME	LOCATION	DATE
Mayaquez Operation	SOUTHEAST ASIA	MAY 1975
Urgent Fury	Granada	Oct – Nov 1983
El Dorado Canyon	Libya	Apr 1986
Just Cause	Panama	Dec 89 – Jan 90
Desert Shield	Southwest Asia	Aug – Dec 1990
Desert Storm	Southwest Asia	Jan – Mar 1991
Restore Hope	Somalia	Dec 92 – Mar 94
Allied Force	Kosovo	Mar – Jun 1999
Able Sentry	Macedonia	Ongoing
Uphold Democracy	Haiti	Ongoing
Deny Overflight	Bosnia	Ongoing

Figure 1.1—Recent U.S. Foreign Military Experiences

A Critical Battlefield Situation: Supporting Light Infantry

The review of the defense planning and guidance literature and the experience of past conflicts indicates that supporting light infantry poses problems that are very different from those for mechanized combat that were explored so exhaustively during the Cold War. Among the important differences are

- A more limited ability to effectively shape the close battle through interdiction and deep fires,
- The generally closer proximity of adversary forces in the close battle,
- Target acquisition and identification difficulties,
- Greater potential for collateral damage and casualties,

- Fratricide, and
- Extremely short response times.

These situations may potentially result in sharp differences in close support needs and make unique demands on system characteristics.

Analyzing Possible Future Scenarios

As a final step in the assessment process, the study team analyzed the types and characteristics of possible future conflict scenarios that might confront the U.S. Our approach had three steps:

- Identify the fundamental characteristics that define and distinguish different scenarios and define the "scenario space."
- Determine how well our scenarios cover the appropriate regions of this space and refine the scenarios as necessary.
- Determine which battlefield situations within these scenarios were important to combat outcomes and thus to close support analysis.

To aid us in this process, we have relied on the concept of scenario space and an analytic technique designed to foment expert consensus, which is known as the Delphi method.[4]

The theater-level scenarios we developed for our analysis included

- A revolution in Cuba,
- A North Korean invasion of South Korea,
- A Former Soviet Republic conflict with Poland, and
- A new war in the Persian Gulf.

The original suite of scenarios also included a major contingency involving a separatist conflict in Georgia and a Former Soviet Republic conflict with Romania. The first of these was dropped as it became too similar to the actual world situation for practical use in analysis and promised to add little to our research. Based on our Delphi experiment and discussions with our project sponsors and RAND colleagues, we subsequently reshaped the Romanian scenario into a conflict that is based on ethnic strife in the Balkans.

These analytic efforts, which are detailed in Appendix A, underscored a need to define the specifics of these core situations through a more fine-grained analytic approach. As a result, a series of map exercises were conducted for each scenario to detail the U.S. and adversary concepts of operations, to evaluate the specific military actions that would be required in each scenario, and to develop a clearer understanding of the types of battles that would be likely to

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[4]This technique is detailed in Dalkey, 1971.

occur in each. Taken together, the Delphi experiment and the map exercises validated the findings of the previous efforts to assess defense planing guidance and recent U.S. combat experience; it also suggested a third critical battlefield situation.

A Critical Battlefield Situation: Handling "Leading Edge" Problems

A *leading edge* problem is a battlefield situation associated with the early stages of the buildup of U.S. forces in a contingency. These may be the most familiar of the combat situations in that they have many of the characteristics of the combat envisioned during the Cold War: U.S. forces are outnumbered, on the defense, and may be facing an adversary with substantial armored forces. Some aspects have changed, however, in that the emphasis in the current environment appears to be first on managing attrition and then on finding a way to conduct effective operations.

Our scenario development work and the analytic scenario experiments led us to view this situation as perhaps the most important—if only because it appears to be so pervasive, and because it has the potential to be a win-lose determinant in high-stakes, large-scale contingencies like Southwest Asia or Korea. Indicators from each type of assessment pointed in the same direction—the initial phases of a contingency posed important problems for leading edge forces; as a result close battle on unfavorable terms was a strong possibility. In nearly all the contingency scenarios we assessed, there was a time in the evolution of the crisis when the initial forces were much smaller than the adversary force with which they could be confronted. U.S. contingency experience of the recent past (e.g., Somalia and Lebanon) argues that, if successfully challenged, the U.S. is likely to consider the costs too high and withdraw--allowing the entire contingency to be determined by the outcome of one battle (Larson, 1996).

A Prolog to This Approach to Determining Needs

During the course of the study's progress reviews, it became apparent that we had come to focus exclusively on the new battlefield situations that emerged from our analysis of the new defense environment, the nation's emerging strategy, the nation's recent past military experience, and our scenario analysis. Moreover, the determination to avoid the "old think" that characterized many years of study of armor-rich defensive battles in Europe created a certain blindness to armored combat.

Discussions with our sponsor pointed out that Operation Desert Storm embodied a largely unexplored battle posture for mechanized U.S. forces, one in which the U.S. had the initiative, controlled the tempo, and focused on offensive operations. Not only had this situation already been experienced in the last days of Desert Storm, but it is likely that these situations, quite different from the classical European scenario, will characterize future heavy force contingencies at some point during the operation.

It also seemed likely that conducting offensive mechanized operations against a numerically superior foe that was encumbered by inferior tactics, training, and leadership could make significantly different demands for close support. In addition, close support systems capable of

supporting allies and light infantry and of handling leading edge problems, but incapable of supporting offensive mechanized battle, would be fatally flawed.

These considerations added a fourth category to the set of critical battlefield situations that we used to understand future close support needs--supporting mechanized battle in which the U.S. has the initiative.

A new concept of close support is under discussion in the naval community, referred to as Hunter Aviation.[5] This notion focuses on hunter aviation from carriers, although it finds some of its origins in land-based aviation in World War II. The basic thrust of Hunter Aviation, also referred to, dramatically, as Jaeger Squadron X, is that the pilot to a large extent is operating on his own initiative and using his own experience and operational judgments to decide how best to contribute to the effectiveness of ground forces. There are clearly some C3I details that remain to be worked out, including whether the Army's rotary-wing and the Air Force's fixed-wing forces will "buy into" the concept. Also, it remains to be seen how fundamental the notion of low/slow aircraft (such as the T-34 trainer) is to the concept.

Exploring These Future Close Support Needs to Understand Desirable System Characteristics

The set of battlefield situations in which close support may prove critical to combat outcomes provides a rough measure of close support needs in future conflicts and provides the framework within which to assess the desirable system characteristics that can meet these needs.

Figure 1.2 summarizes the critical battle situations where close support would be needed. It also illustrates the overlapping nature of these situations—for example, handling leading edge problems may involve supporting light infantry forces.

The rationale underpinning this set of needs-defining situations can be summarized as follows:

- *Augmenting Allies*—Supporting allies and other coalition partners is a pervasive element of the literature that decides U.S. defense policy and strategy. It seems clear that the U.S. will seek to employ its forces in a coalition context for political and diplomatic as well as military reasons. This is likely to lead to situations in which the U.S. is relied on to provide close support to allied forces that are deficient in these capabilities and will have shortfalls in the doctrine, training, and equipment necessary to effectively interface with the U.S. forces providing such support.

[5] For a discussion of the new concept, see Wyly, 1995.

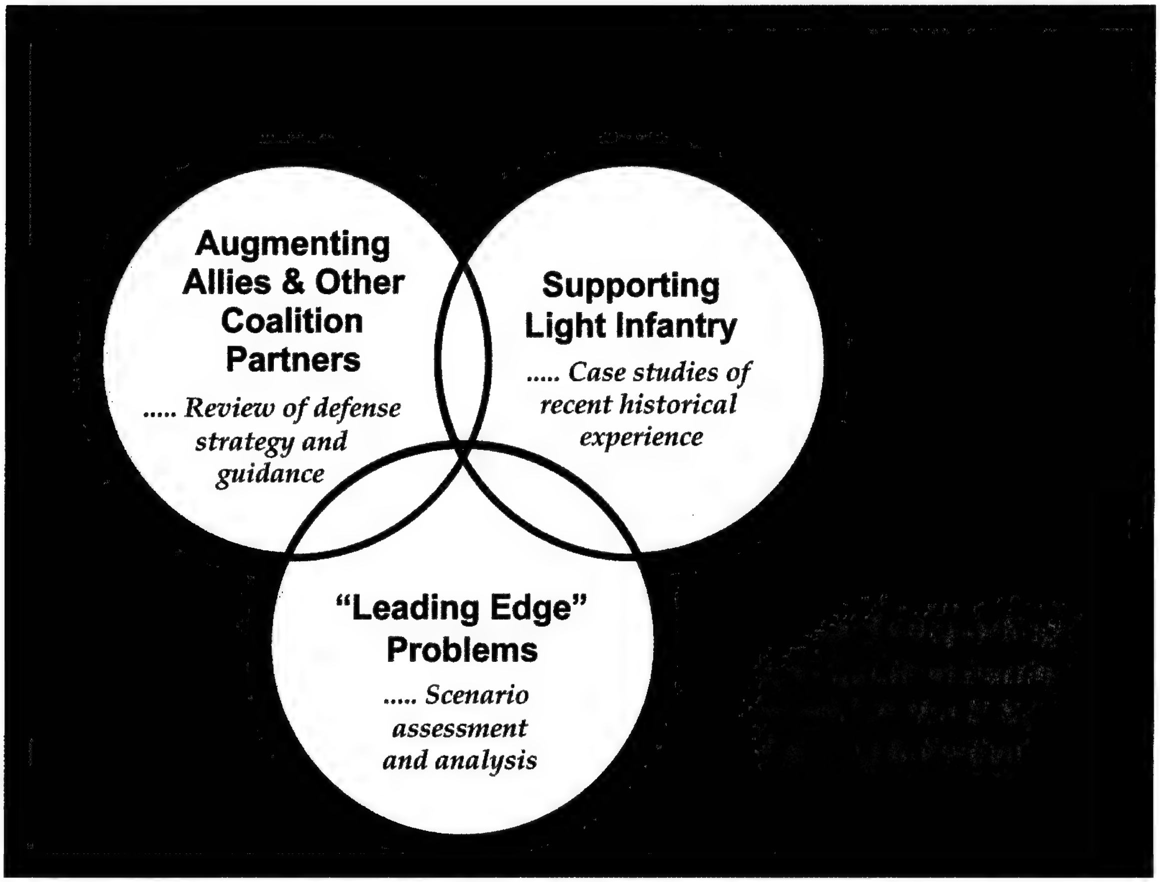

Figure 1.2—Need for Close Support Is Determined by Critical Battle Situations

- *Supporting Light Infantry*—Analysis of recent U.S. military operations has shown that the U.S. frequently relies on the employment of light infantry forces either because of their appropriateness to the terrain or because of their ability to be rapidly deployed in a crisis. Light forces have great "strategic" mobility. They do not have the firepower to face heavy mechanized forces, and, perhaps more important, they lack the "tactical" mobility to avoid being overrun. Such forces may require close support to provide additional firepower and to offset their lack of firepower and tactical mobility.
- *"Leading Edge" Problems*—Our future scenario analysis highlighted situations associated with the early stages of the buildup of U.S. forces as one of the most critical stages of a conflict in many future contingency operations. The early forces are often light infantry forces, but even when leading edge forces are armored units, the initial force ratio enjoyed by an adversary can strain U.S. capabilities. Should interdiction and other battle-shaping applications of the deployed force fail or be precluded by the timing of the onset of hostilities, close support may be needed to ensure a successful battle outcome in the critical initial engagements.

- *Supporting Mechanized Offensive Operations*—The likelihood of conducting offensive mechanized operations at some point during a conflict in the new defense environment is much higher than in the past. In addition, close support systems that were capable of supporting allies and light infantry and of handling leading edge problems, but incapable of supporting offensive mechanized battle, would be fatally flawed.

In order to form an appreciation of the needs for close support from these battlefield situations, it was necessary to select specific combat vignettes and develop them in the detail suitable for analysis. Our aim was to be able to perform analytic experiments with our combat simulation models to determine how much additional support would be necessary to produce a favorable battle outcome for the supported force and thus provide a rough measure of close support needs.

Choosing Specific Combat Vignettes to Represent These Critical Battlefield Situations

Based on the analyses of recent U.S. combat experience, the map exercises we applied to the scenarios, and our experience with past close support analyses, we selected a set of more specific combat situations (which we term combat vignettes) that are broadly representative of the range of critical close support situations the U.S. might face and typify the scenarios implied by the new defense environment. These are

Augmenting Allies

- Escort of a Humanitarian Convoy
- Support for an Allied Enclave

Supporting Light Infantry

- Small Unit Infantry Assault
- Small Unit Infantry Patrol

"Leading Edge" Problems

- Hasty Defense by Light Forces
- Prepared Defense by Light Forces

Supporting Mechanized Offensive Operations

- Armored Force Meeting Engagement

While we have cataloged each of these under a battlefield situation that it clearly represents, each vignette (or variants of these vignettes) could be found in other situations as well. For example, meeting engagements between armored forces can occur in "leading edge" situations or even in situations in which the U.S. is called upon to support allied forces. As such, this collection of combat vignettes can be thought of as typical of the new defense environment and a litmus test for close support, and can provide the basis for the study's detailed combat assessments, but it should not be considered definitive.

Because these critical combat situations can take place against an armored or infantry adversary in both offensive and defensive situations, we need to provide one more level of specificity before developing combat vignettes that are appropriate for the analysis of close support issues. In Figure 1.3 we partition the battle space more finely to better appreciate the analytic requirements that we must satisfy. The figure characterizes (as light infantry or armored forces) the type of U.S. and coalition and adversary forces involved in the battle. It also denotes the posture of the forces as offensive or defensive.[6]

The following situations (not denoted by a starburst in the figure) were assessed to provide little new information and consequently were not explored in this analysis:

- The situation in which U.S. light infantry would attack an adversary's armored forces was judged a misuse of an asset.
- The Escort of the Humanitarian Convoy could probably be characterized as light infantry initially on the defense but switching over to the offense as the vignette unfolds.
- The situation in which U.S. armored forces defend against a light infantry adversary was judged to be a case in which the U.S. has a more than adequate capability and therefore would not likely require close support.
- Finally, when the adversary's armored forces are on the offense and U.S. armored forces are on the defense, the situation is one that the defense community has studied exhaustively for 50 years. Analysis would not likely yield significant new information.

[6]A simplification is that if U.S. forces are on the offense then the adversary forces are on the defense, and vice versa.

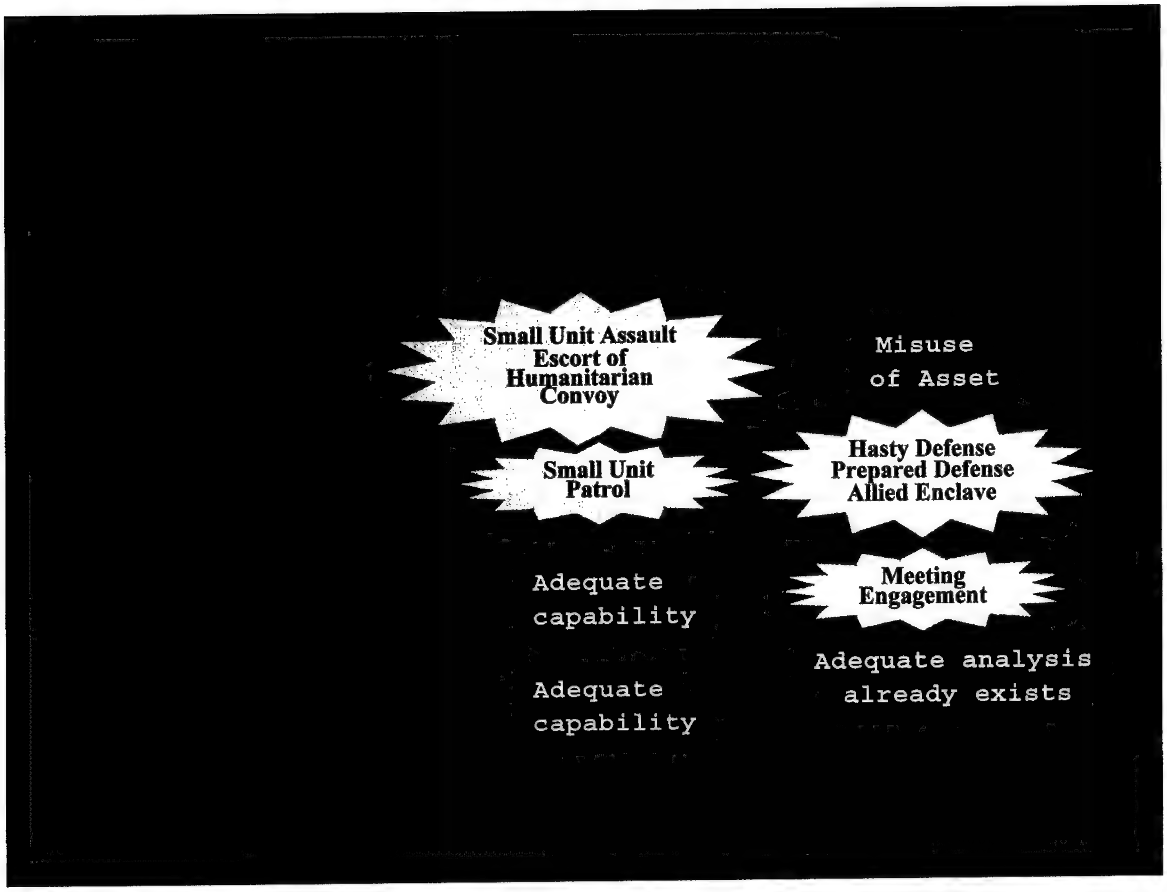

Figure 1.3—Vignettes Cover a Broad Spectrum of Combat Operations—But Emphasize the New Defense Environment

The starbursts identify vignettes that are typical of combat situations where close support may be critical to battle outcomes. These situations were developed in detail according to the posture specified in the figure and used as the basis for our analysis.[7] For example, U.S. light infantry on the offensive against an adversary's light infantry was studied in a vignette involving a small unit assault on a guarded facility that houses either a special person or a special weapon that is the objective of the assault. U.S. light infantry on the defense against an adversary's light infantry was analyzed in a vignette that describes the ambush of a U.S. patrol in an urban setting.

These vignettes were developed in the context of the theater scenarios that grew from our earlier scenario analysis work. This provided the larger context that was needed to properly weigh more strategic considerations. For example, the level of losses acceptable to friendly forces in an engagement (which helped us establish the criteria for satisfactory outcomes) is largely determined by the theater-level situation. Similarly, the time urgency associated with the battle

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[7]These vignettes were developed for use in RAND's tactical combat simulation environment. It consists of a networked system of databases, analysis tools, and models, including JANUS (a ground combat simulation), CAGIS (a cartographic information system), BLUE MAX and CHAMP (flight path simulations for fixed- and rotary-wing aircraft), and a number of more detailed engagement models. The system is described more fully in Appendix B.

is also driven by the theater-level context in which that battle is fought. For example, in a meeting engagement situation where the adversary has assumed a hasty defensive posture, the U.S. commander has the option and time to delay starting his assault to properly prepare the battlefield if the theater-level situation argues that the adversary's follow-on forces are some distance away.

In each of these cases, we conducted analytic experiments with our combat simulation models to determine how much additional support would be necessary to produce a favorable battle outcome for the supported force.

Each of these vignettes is described in depth at the beginning of each of the sections that present the close support analysis (Chapters 2, 3, 4, and 5).

Issues as a Means of Focusing Needs on Important System Characteristics

The set of battlefield situations in which close support may prove critical to combat outcomes provides a basis for measuring close support needs in future conflicts. In order to develop an appreciation of those needs, it was necessary to develop detailed specifications of these battles (combat vignettes) that were suitable for use in our suite of combat simulation models. This allowed us to perform analytic experiments with our models to determine how much additional support would be needed to produce a favorable battle outcome for the supported force. These needs, and the representative combat vignettes that we used to determine what they are, provide a framework within which to assess the desirable system characteristics that can meet these needs.

In order to use this framework in a practical way (within the resources available to the study), we needed to focus our efforts on the key issues surrounding close support system characteristics.

By considering the information developed in the first-order analysis conducted during the initial phase of the study (Mesic et al., 1994), and by studying the questions that arose when we considered the interaction of the close support assets with the various combat situations, we developed a set of issues—unanswered questions—associated with the characteristics of fixed-wing, attack-helicopter, and advanced-artillery systems. These focusing issues are summarized below.

Fixed-Wing Issues

A. What level of tactical standoff is most practical for current fixed-wing system attack profiles?

B. What fixed-wing speed/signature control is useful in providing close support to deeply inserted forces?

C. How can fixed wing-systems engage more effectively (with faster kill rate) within the attrition management window?

D. What munitions and sensor characteristics best match fixed-wing engagement profiles?

Attack-Helicopter Issues

E. What helicopter characteristics are most useful in making the attrition/effectiveness tradeoff?

F. How can helicopters engage and operate more effectively within the attrition management window?

G. Does a requirement to penetrate to the battle location influence this?

H. What munitions and sensor characteristics best match rotary-wing engagement profiles?

Advanced-Artillery Issues

I. What are the characteristics of an effective close support artillery system?

- Footprints
- Target types

J. What munitions and sensor suites best match artillery's indirect fire method of engagement?

K. What effect can small, deployable packages of advanced artillery have on battle outcomes?

L. What alternative missions are required of artillery?

In addition to these system-based issues, several key questions were identified in the initial analyses that were more strongly correlated with information systems, sensors, cueing, fire control, and munitions.

Information Systems, Sensors, Cueing, and Fire Control Issues

- What is the value of a virtual-presence target-sensing profile (such as that used in NLOS/FOG-M) to close support?
- What contribution would a tactical information system capable of surveillance, targeting, and reconnaissance make to battle outcomes?

Munitions Issues

- What fixed-wing munitions concepts can overcome the inefficiency of narrow weapons patterns (like Skeet)?
- Can current single-shot systems (e.g., Maverick) be provided a sufficient multiple-target engagement capability to influence battle outcomes?

We used these key issues to focus our analysis on the most important system characteristics for meeting the close support needs defined by our critical battlefield situations as typified by the combat vignettes. In essence we asked the question: Which combat vignettes will shed the most light on this issue? The answer allowed us to use the project's resources effectively, as it was not possible to fully assess all issues in each vignette.

Matching Situations to Issues to Analyze Close Support Needs and System Characteristics

In formulating the best system-vignette match, we first considered the overall theater context and the operational imperatives associated with using a particular close support system in a given situation. Based on this, we eliminated a number of system-vignette combinations from consideration. For example, we judged both fixed-wing and advanced-artillery employment requirements as so limiting in escorting humanitarian convoys that we elected to focus solely on attack helicopters. We also sought to examine an issue in only one vignette unless analysis in a second promised to provide substantial additional insight. This matching is illustrated in Figure 1.4.

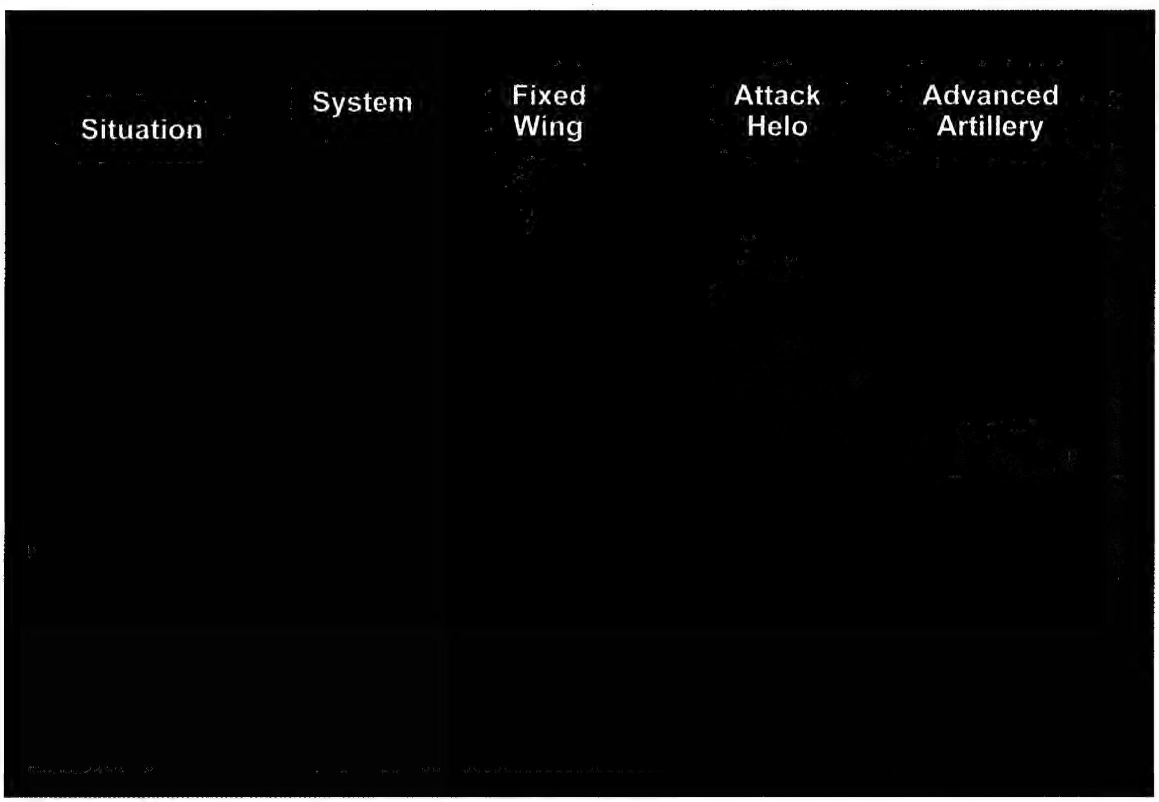

Figure 1.4—Vignettes and Issues Have Been Carefully Matched to Understand Close Support Needs and System Characteristics

Preliminary analysis of the allied enclave situation convinced us that fixed-wing systems were the most practical means of providing close support in the majority of these situations. The attack helicopters would often be range limited because many enclaves were likely to be significantly deep in contested territory, and advanced artillery would have limited firing positions vulnerable to counterbattery fire because of the siegelike setting of the vignette.

As alluded to above, in the humanitarian convoy situation, the low speed of the vehicles would greatly complicate the mission for fixed-wing assets if they were to escort, and response times

would be too long to match the problem even if they were on dedicated alert. The distance traveled by the convoy (typically to towns in the interior) argued that artillery support might be problematic unless a fire support base concept were used, and this was deemed incompatible with the overall scenario in which the humanitarian convoy operations took place. Additionally, the winding nature of most roads would make the use of advanced artillery for close support very difficult. As a result, the study team determined that the analysis would have the greatest payoff from examining the desirable characteristics for attack helicopters for use in this situation.

Movement rates in the urban patrol are even slower than those for the humanitarian convoy, and close support with fixed-wing aircraft would be commensurately more difficult. In addition, the urban setting makes target acquisition very difficult for the fixed-wing assets, which require continuous movement to maintain flight. Collateral damage is a concern for both fixed wing and many advanced artillery systems, due to the large warhead emphasis of many of the munitions concepts for these two platforms. Building masking and other restrictions to lines of sight and fields of fire pose problems for all three systems. Even though attack helicopters were judged a problematic candidate for close support for the urban patrol, they promised the greatest payoff for analysis in terms of what we might learn about the system characteristics needed to handle such challenging situations and so were chosen as the basis for the analysis in this vignette.

The special assault mission promised to be a poor candidate to shed light on fixed-wing issues, since the key questions about fixed-wing characteristics revolved around survivability and kill rate, whereas the needs of the vignette deal largely with surprise and the requirement to counter a few critical targets.[8] Low-observable attack helicopters and man-portable advanced artillery held significant promise for this situation; further, they raised key questions as to what characteristics would be needed to make such systems effective. As a result, these vignette-system combinations were selected for analysis.

The Hasty Defense by Light Forces vignette promised to provide little new information for attack helicopters due to its similarity to what has been substantially analyzed in the past—the traditional armored battles set in Central Europe (U.S. forces are outnumbered, on the defense, and may be facing an adversary with substantial armored forces). The employment of advanced artillery appeared problematic in this scenario due to the compact area that friendly forces controlled, which made artillery deployed with the insertion force highly vulnerable to enemy artillery. Additionally, the tenuous lodgment associated with leading edge forces argued that fire support bases would be neither established nor viable at this point in the conflict. Finally, a key-fixed wing issue dealing with deeply inserted forces could most credibly be addressed in this vignette. As a result, the study team focused its analysis on fixed-wing issues in this vignette.

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[8]As explained in a later section, this initial judgment proved faulty, and a joint systems approach that included fixed-wing assets was employed in this vignette. While this does provide some insights as to the need for low-observable signatures for fixed-wing assets, the need is both obvious and met with current assets (e.g., F-117s), which could certainly be committed to the operation, given that it is inherently a high-priority effort.

The new naval Hunter Aviation concept could be appropriate in this vignette because of the island setting.

Similar arguments obtain for the Prepared Defense by Light Forces vignette, except that the more mature buildup of forces in theater argues that some forms of advanced artillery (especially small, deployable packages) could be available. Previous analysis and the experience of attack helicopter operations in Desert Storm imply that attack helicopters have a substantial capability against exposed armored forces (either when supporting friendly forces on the defense or engaging enemy forces that can not assume an effective defensive posture). Because of this and because fixed-wing issues could best be addressed by other vignettes, the study team focused its efforts on advanced artillery.

The Armored Force Meeting Engagement presented the study team with a range of new considerations for armored combat due to the offensive posture of U.S. forces. Preliminary analysis indicated that, with the defenses available to the adversary and in the absence of advantageous weather conditions such as were enjoyed in the battle of 76 Easting during the Gulf War, it is difficult to effectively employ attack helicopters against a defensively postured adversary that is typically in defilade. This is because of the low graze angles that are the consequence of survivable attack profiles for helicopters (firing from masked positions at long standoff ranges). Advanced artillery with relatively steep attack profiles promised greater utility and, if closely coupled to the supported commander, might be so well integrated with the battle plan that practically no delay would be necessary for shaping the battle with a preliminary missile engagement. While fixed-wing might be expected to require more of a pause due to the time it might require to mass airpower, its all-aspect attack advantages against an island of adversary forces (even a heavily defended one) promised significant advantages. Additionally, our theater scenario analysis argued that there was adequate time available for such an air operation before starting the assault. As a result of these considerations, the Armored Force Meeting Engagement vignette analysis was focused on fixed-wing and advanced-artillery issues.

Reporting the Results of the Analysis

In Sections 2 through 5 of this report we analyze the four major categories of critical combat situations to determine the needs of future ground commanders and the desirable characteristics of systems that can provide this support. We use the combat vignettes outlined above as the framework for analysis and report our findings by addressing each of the fixed-wing, rotary-wing, and advanced-artillery issues outlined above. Section 6 reports on the implications of our analysis for future close support.

2. Augmenting Allies

It seems clear that the U.S. will seek to employ its forces in a coalition context. These situations appear to be characterized by a wide range of limitations and constraints that arise because of differences in doctrine, communications, training, equipment, and experience in working with U.S. forces. Further, differences in allied ground force capabilities (lack of adequate combat power) and approach to the conflict (excessive aggressiveness or hesitancy) may invite or force close battle with the enemy, thus increasing the need to *augment allies and other coalition partners* with close support at levels above those that the U.S. would plan for if supporting only U.S. ground forces.

We have selected two vignettes as representative of these battle situations:

- Escort of a Humanitarian Convoy
- Support for an Allied Enclave

Escort of a Humanitarian Convoy

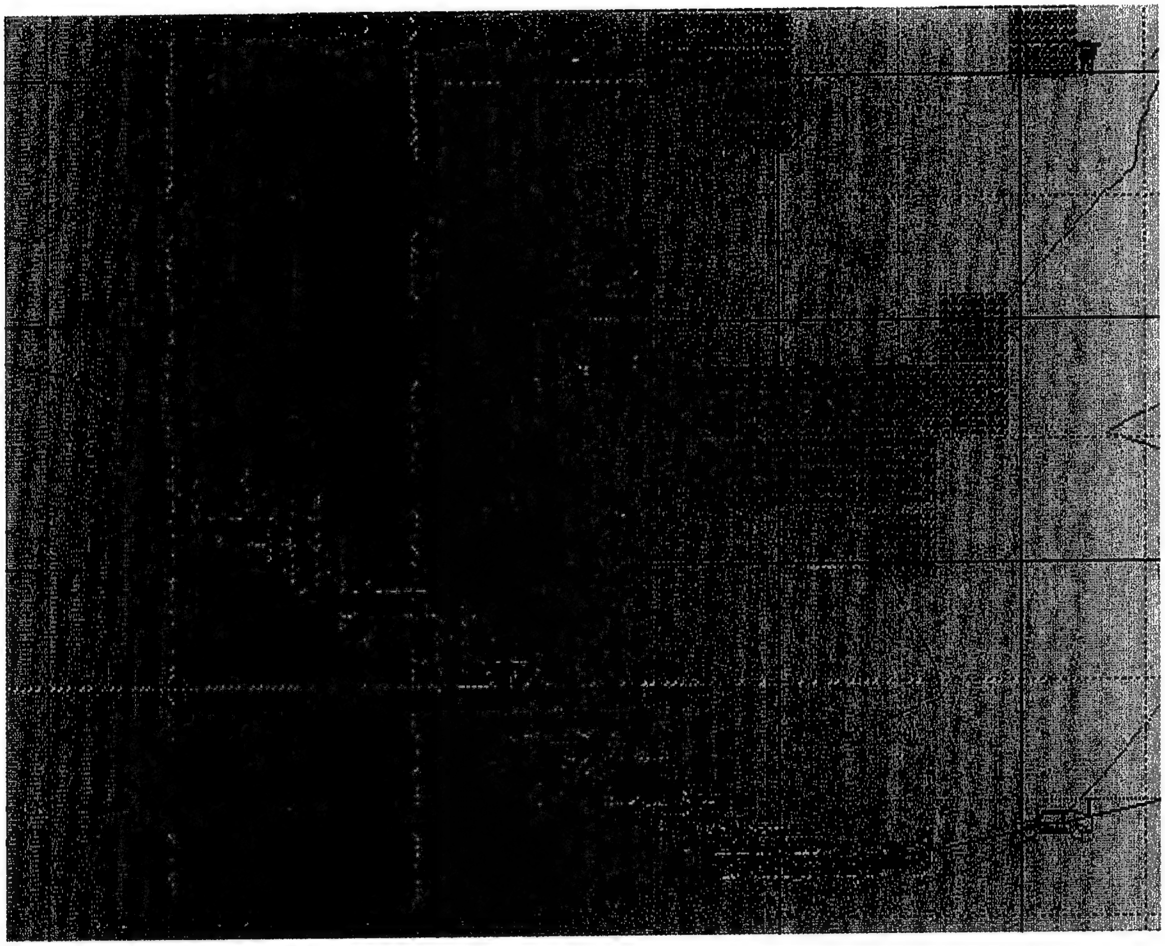
Ambush engagements are typical of light infantry combat and leading edge situations in which large areas are contested. Battlefield situations of this type could be found in each of the major scenarios we examined in the scenario assessment and map exercise phases of this analysis.

Ambush engagements are often characterized by a relatively long preparation phase lasting hours or days (especially if the attacking force is infantry and needs to march to the ambush site) and an intense and short combat phase lasting minutes or tens of minutes, followed by a disengagement/pursuit phase that may be comparable in length to the preparation phase. Typically the force under attack is a large, "lucrative" target (including multiple logistics/troop transport vehicles not well configured for fighting) and is constrained by the terrain (e.g., limited to movement on a road). Historical examples abound; one that is particularly well documented is an ambush that took place on National Highway One during the Vietnam conflict in November of 1966 (Cash, 1985).

JANUS Vignette—Escort of a Humanitarian Convoy

We have developed a prototypical combat situation for JANUS that captures many aspects of the ambush of a convoy when modern weapons are involved. While ambushes could occur in each of the theater-level scenarios we examined, we chose the heavy force contingency in northcentral Europe as the setting for this vignette. In it a RED ambush force consisting of 24 light infantry troops moves in a 13-hour march to an ambush position to set up on an east-west road segment

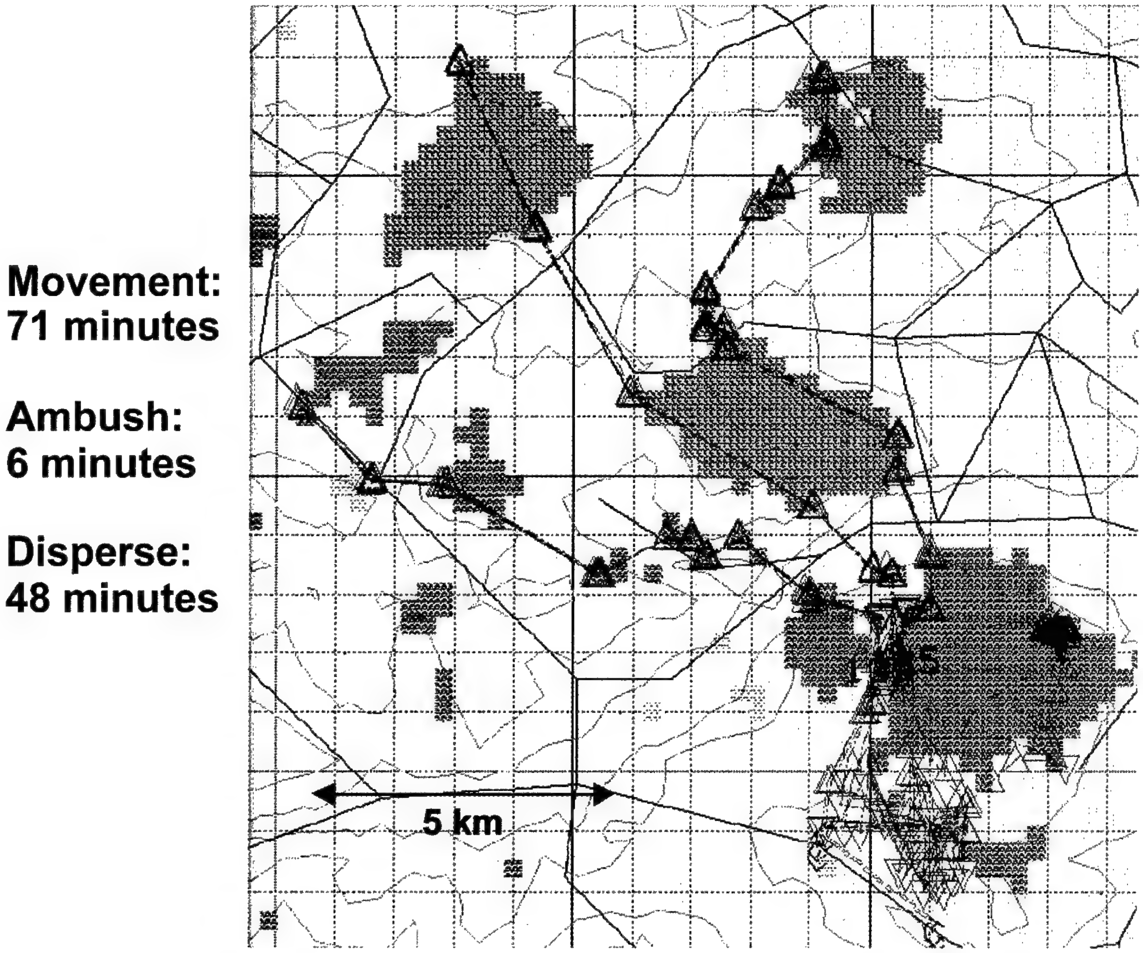
as shown in Figure 2.1. (Unless otherwise noted, all vignette maps in this report observe the convention that North is at the top of the page.)



Source: RAND analysis

Figure 2.1—Escort of a Humanitarian Convoy: Ambush

The team is equipped with man-portable anti-tank weapons and mines; its ammunition is limited to what can practically be carried during the march. As shown in Figure 2.2, the troops follow an indirect route to avoid compromising the location of their ambush site should they be detected.



Source: RAND analysis

Figure 2.2—Escort of a Humanitarian Convoy: Ingress and Egress Paths of RED Members of the Ambush Team

This vignette is composed of a small BLUE force consisting of 10 M2 .50-caliber machine guns mounted on high-mobility, multipurpose wheeled vehicles (HMMWVs) escorting a GREEN allied convoy consisting of 30 medium tractor-trailer trucks carrying supplies for an allied enclave. The RED force consists of 24 light, irregular infantrymen armed with light machine guns and light to medium anti-tank weapons. The RED force infiltrates into the BLUE/GREEN rear area with the intent of setting up an ambush on the main supply route (MSR). Their mission is to destroy the BLUE/GREEN convoy and the supplies. The ambush is linear and conducted from near to far in range from the MSR. Upon completion of its mission, RED is to egress by foot and exfiltrate back into friendly territory by blending in with the indigenous population.

The terrain on which the vignette is set is rolling hills with moderate foliage with a well-established road network. The weather is good, and the base case is defined by current force capabilities for both RED and BLUE.

The team sets up its killing zone along 3000 meters of road using the range of its missiles to distance itself about 1000 meters from the killing zone in positions on the south side of the road

(depicted by the troop symbols in the figure). At the east and west ends of the killing zone, the road will be cut by cratering devices (shown by a large "C" in the figure). The terrain over the ingress route and in the ambush area is rolling to broken with moderate foliage cover.

A BLUE convoy consisting of 10 escort and 30 support/supply vehicles moves from east to west along the road in a doctrinal road-march convoy. The convoy's movement from its jump-off point to the killing zone takes about 3.5 hours and covers about 70 km (20 kph).

Situation Assessment

For each of the vignettes used in this study, we determined a success criterion for each of the forces involved in the battle. The assessment took account of the point at which a unit would no longer be able to conduct its immediate mission, whether it was required to conduct other actions without reinforcement in the larger theater-level scenario, and how frequently the situation in the vignette would need to be faced. Our overall scenario analysis (reported on in Appendix A) set the larger context for each of the vignettes used to assess our critical combat situations. This allowed us to make judgments about important considerations beyond the vignettes used in the simulations, which in some cases lasted only minutes. The success criterion for the BLUE/GREEN force in this vignette is determined by how well the convoy can be protected during the ambush. Since the purpose of the convoy is to provide supplies at a given location, not to cause RED casualties, convoy survivability was chosen as the primary measure of effectiveness (MOE). We estimated that BLUE/GREEN would not accept a loss rate of over 4 percent for humanitarian operations over the long run. The losses suffered by the RED force were not included in the success criterion, except for their indirect effect on BLUE/GREEN survivability. This is because an adversary could sustain ambush operations even if high casualties were imposed on such small ambush teams, so long as a sufficient number of the convoys could be subjected to ambush. The success criterion for RED is measured in terms of how much of the convoy the attacking force destroys.

The engagement phase begins when the convoy enters the killing zone and reaches the trigger point. The engagement takes less than 10 minutes to play out and typically results in the loss of about 20 convoy vehicles when RED breaks off the attack and withdraws. This base case situation embodies an escort response but no use of close support assets. The simulation continues through the disengagement/pursuit phase (see Figure 2.2).

The base case results in the attrition shown in Table 2.1. With the loss of about three members of the ambush team, the RED force destroys about half the convoy, approximately 15 trucks. These results make the ambush a very attractive tactic for RED, and make it virtually impossible for BLUE to sustain such losses for even a short time period.

Table 2.1

Escort of a Humanitarian Convoy: Base Case Results

Systems	Start	End	Percent Survived	Percent Total Force Surviving
BLUE				
Trucks	30	14.6	49	
HMMWVs	10	4.7	47	49
RED				
Ambushers	24	21.7	90	90

Source: RAND analysis.

Figure 2.3 shows the results for this situation when the ground force is enhanced. The filled-in square in the figure shows the results of the baseline engagement. Roughly 45 percent of the GREEN trucks are destroyed, and only two members of the ambush team are killed. In an attempt to achieve a more desirable outcome, the engagement capability of the BLUE escorts was enhanced. The upgraded force closest to the base case in capabilities had systems with the capability to engage targets in 87.5 percent of the engagement time needed by the systems used by the base case force. The next points represent upgraded forces that took only 75, 50, and 25 percent of the time it took for the base case force systems to engage a new target. The systems in the most capable of the upgraded forces (the point farthest to the right on the chart) are able to engage a new target in essentially zero time. This improved target engagement time can be thought of as a surrogate for improved sensor, cueing, or C4I capability for the BLUE/GREEN forces. The point to the right of Figure 2.3 shows the results when the HMMWV escorts are replaced with Bradley fighting vehicles. Although the Bradleys are more lethal than the HMMWVs, the survivability of the BLUE/GREEN forces is not improved.

The substantial, notional enhancement only improved the GREEN survivability to about 55 percent with three members of the ambush team killed. Improving the offensive capability of the escort forces does little to reduce the negative impact of the ambush. Two interesting results emerge from this chart and are evident in the subsequent cases as well. First, improving the engagement capability of the ground force makes it more lethal, as would be expected. However, upgrading the ground force does not have as pronounced an effect on the BLUE/GREEN survivability.

The introduction of Bradley fighting vehicles in place of the HMMWV escorts may be a partial solution, but it does not solve the basic problem of substantially improving the GREEN survivability. It changes the nature of the deployment and allows the convoy escort to provide a considerably more aggressive execution of its mission. It might, however, change the priority for target selection by the heavy weapons teams of the ambushing force, which would result in the Bradleys being preferentially targeted.

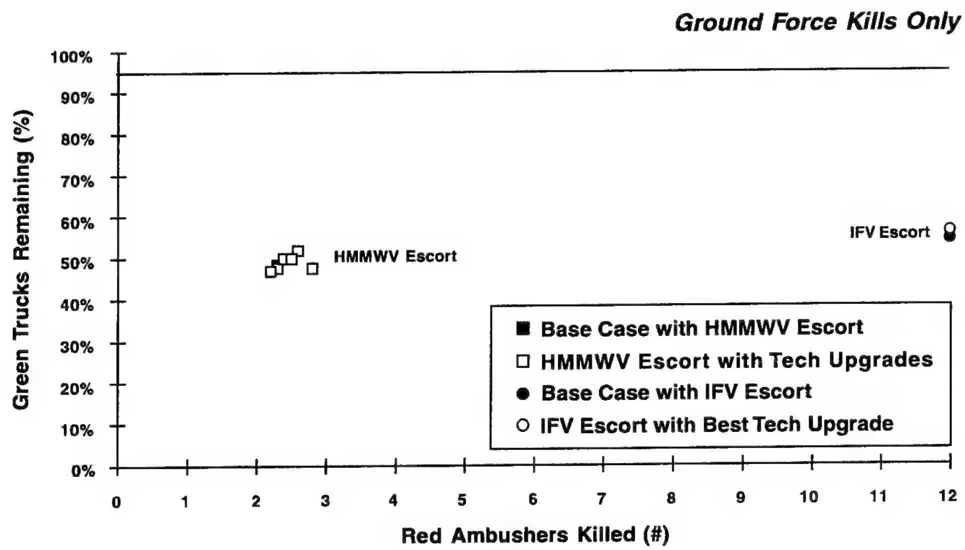


Figure 2.3—Escort of a Humanitarian Convoy: Force Performance When Ground Force Capability Is Enhanced

Figure 2.4 depicts the performance of the BLUE forces when notional close support is employed to reduce the capability of the ambushing forces. The analysis was carried out by parametrically removing the *most valuable* RED forces from the vignette in order of priority before the battle was joined.[1] In this way we are able to simulate a situation in which close support is used in the most effective manner possible in the scenario (e.g., it was completely effective in eliminating the most valuable targets). The analytic construct simulates the maximum potential effect of some form of close support so that we can understand its greatest potential impact in this combat situation. This also allows us to understand how the effects of close support change the performance of the ground force in the scenario. In this way we can evaluate how the use of close support changes the targets available to the ground force and the attrition it suffers. This does not address the ability of the various systems we are assessing to actually provide these levels of close support. Such issues are addressed in the systems analysis excursions that follow the scenario assessments—-if the potential impact of close support indicated by the scenario analysis is sufficient to warrant further examination of the systems.[2]

In the figure, the point closest to the base case had three anti-tank gunners removed from the ambush. The next three points (moving upward on the graph) show the effects of removing six, eight, and 10 anti-tank gunners from the RED force before the ambush commences.

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[1] That is, the RED forces that would inflict the greatest damage on BLUE in the base case were removed. The specific force elements that were selected were determined by analysis and computational experiment. Due to the dynamics of combat simulated in these scenarios and the fact that the battle that results after any change in capability is different from the battle that obtains in the base case, this analytic technique can provide only an approximation of the best targets to attack. (See the analysis of the Prepared Defense by Light Forces vignette in Section 4 for a discussion of the improvements in scenario outcome that an adaptive targeting system can provide.)

[2] For a host of real-world reasons (e.g., Pk less than one, acquisition constraint, and close support system attrition), the capabilities of the systems assessed in this study have a lesser impact on RED forces in our simulations than does the notional close support used in the scenario assessments.

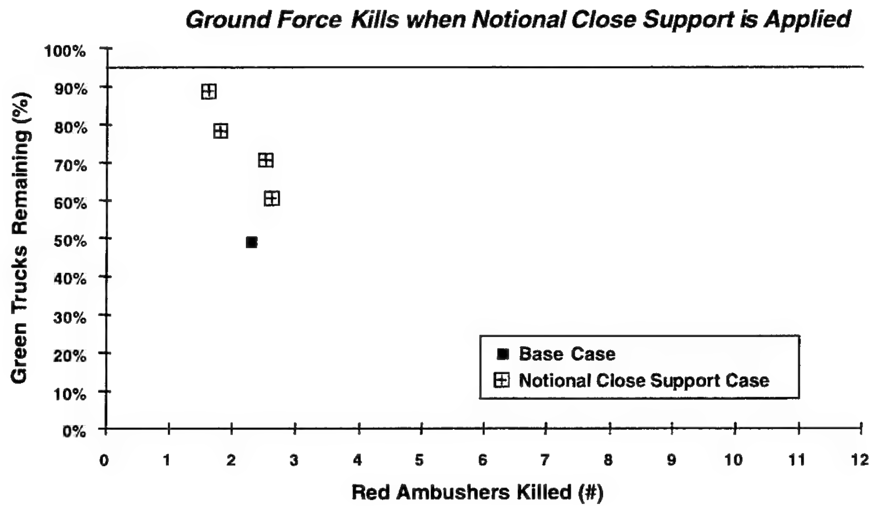

Figure 2.4—Escort of a Humanitarian Convoy: Ground Force Performance When Notional Close Support Is Applied

The clear picture that emerges is that as the close support reduces the initial number of RED forces in the ambush, the GREEN survivability improves substantially, but the number of members of the ambush team killed by the BLUE escort force decreases. This is apparently the result of the reduced availability of targets for the BLUE forces to engage.

Figure 2.5 shows the number of RED ambush team members killed by the combination of notional close support (the number of anti-tank gunners removed is annotated next to the point) and BLUE escorts. Not surprisingly, as the amount of close support increases, the GREEN convoy trucks survive better and more members of the ambush team are killed.

Combined Ground Force and Notional Close Support Kills

Note: The number below each point indicates the number of ATGM gunners removed before the simulation began.

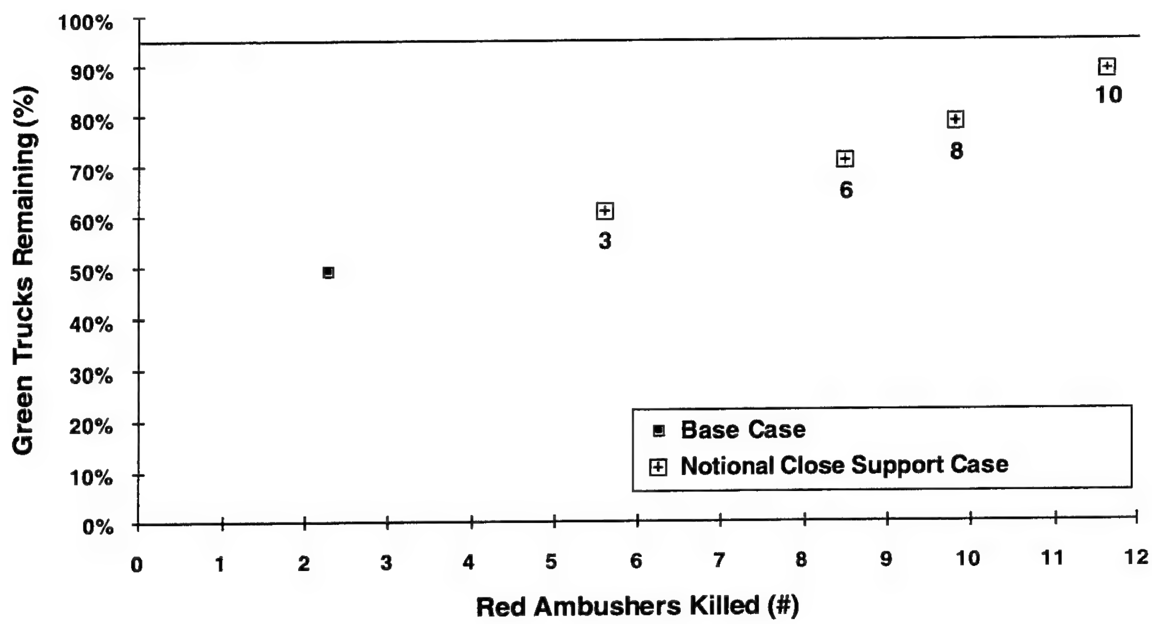

Figure 2.5—Escort of a Humanitarian Convoy: Combined Close Support and Ground Force Effects on the Battle

Observations on Future Close Support Needs and Desirable System Characteristics

Actual systems are subject to constraints that limit their capabilities in comparison to the notional close support. Because substantial losses by BLUE/GREEN could not be precluded even in the extreme notional close support cases, we did not conduct a full analysis of the actual, less capable systems. Since the whole engagement is over in 10 minutes, fixed-wing systems would have to be on a local combat air patrol (CAP) in order to arrive in time to make a difference. Target acquisition problems make the fixed-wing option unattractive, even if targets can be designated by the escort force. Advanced artillery systems provide similar challenges. Detailed fire support plans and complex communications would be required, and collateral damage would be a serious consideration.

We did, however, examine some aspects of actual system capabilities. In one of these assessments, four helicopters arrived on the scene 10 minutes after the start of the ambush and conducted a pattern search centered on the ambush site. Within 60 minutes of the start of the ambush, they had detected 23 of 24 members of the ambush team during their egress from the ambush area. This implies that present sensor technology satisfies the close support requirement after the ambush (a much less challenging criterion—significantly damage or destroy the ambush force). However, it must be noted that the members of the ambush team were egressing through

unpopulated countryside, and the requirement to distinguish the enemy from innocent noncombatants was not required.

Our analysis of this vignette resulted in three major observations:

Responsiveness is a key requirement for close support but masks the need to keep the ambush team from firing at all. The short duration of the ambush makes responsiveness an almost impossible requirement for close support. Dedicated fixed-wing or attack-helicopter assets flying "CAP" for the convoy can respond in minutes. Helicopters can be sufficiently lethal to impose significant attrition on the members of the ambush team. But neither can respond quickly or lethally enough to preclude the effects of the ambush. Real-world constraints compound this problem. As was observed in Afghanistan, the introduction of shoulder-held SAMs can make the attack helicopters a lucrative target. The requirements for escorting convoys can increase the forces needed for support beyond in-theater capabilities. Advanced artillery support requires an extensive, detailed fire coordination plan, real-time communications, and timely movement of the fire units. In short, we see no practical solution to the ambush problem using close support in a responsive mode.

Discriminative retribution may have a deterrent value. If precluding the ambush is not possible, the threat of retribution may deter the enemy from taking part in future ambushes. However, the literature is replete with discussions of the negative implications of indiscriminate retribution.[3] Some form of marking, designating, or tagging the individuals involved in the ambush might be useful so that they could be punished subsequent to the actual ambush.[4] Research into sensing, target discrimination, and marking might prove to be quite beneficial.

Don't get ambushed. Providing enhanced lethality for the escort forces has been shown to be of limited value. Close support kills more members of the ambush team but only marginally limits the losses to the convoy, even in the most effective notional close support case. The importance of avoiding the ambush emphasizes the importance of battlefield information. HUMINT could be quite beneficial in ambush avoidance. Remote sensing could also contribute valuable information. Shoulder-held weapons such as rifles and anti-tank rockets are in effect a dipole. If these could be detected remotely, it could warn of an impending ambush or allow detection of the members of the ambush team on their march to the ambush site. Similarly, high-resolution optical or IR sensors might detect the team as it moves into ambush positions.

Supporting Allied Enclaves

History is replete with siege situations where one force is ensconced in a town or fortification and an adversary is attempting to take possession and control of the enclave. For example, the

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[3]See, for example, Leites and Wolf, 1970.

[4]In a recent interview, a highly placed Defense official related a discussion with a Russian general commanding troops against the Chechen rebels in 1994 at Grozny. When the Russians captured rebel suspects, they stripped them to the waist to see if they had bruises on their shoulders characteristic of firing shoulder-held weapons, such as the AK-47. The method may be crude, but it testifies to the Russian appreciation for the need to avoid indiscriminate attribution.

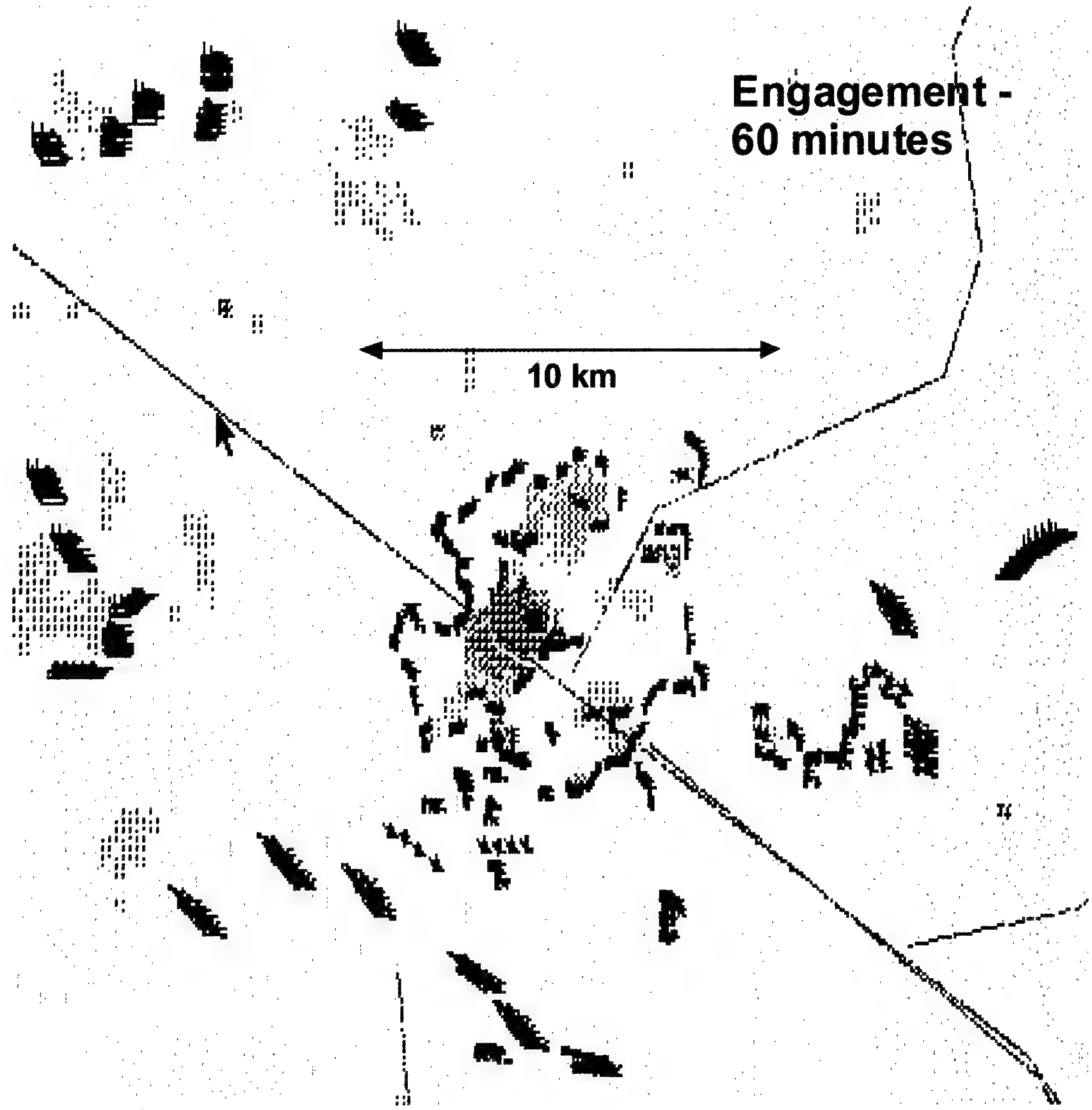
Vietnam conflict involved two famous enclave situations: Dien Bien Phu, in which the communist forces prevailed, and Khe Sanh, in which they did not, due largely to massive close support efforts. Because the Balkan situation operation presents numerous opportunities for enclave situations, we chose the peacekeeping contingency in the Balkans as the setting for this vignette.

JANUS Vignette—Supporting an Allied Enclave

The enclave is defended by a small BLUE force consisting of four tube-launched, optically tracked, wire command-linked (TOW) missile launchers mounted on HMMWVs and six HMMWV Scouts supporting a GREEN allied force consisting of one company of light, irregular infantry in defense of an enclave on the outskirts of an urban population center.

The enclave is attacked by a RED force consisting of approximately three battalions of heavy and medium tracked armored vehicles supported by several batteries of light to medium cannon artillery. The mission of the GREEN/BLUE allied force is to prevent penetration of the enclave by the RED force, whose mission is to eliminate the enclave by inflicting as much attrition as possible on the allied forces.

In order to accomplish its mission, the RED force attacks, as shown in Figure 2.6, with a main attack on the high-speed avenue of approach from the west and two small supporting attacks from the north and northeast.



Source: RAND analysis.

Figure 2.6—Supporting an Allied Enclave: Initial Force Deployments

The vignette is set on hilly, cross-compartmented terrain with limited lines of sight and fields of fire except down the high-speed avenue of approach. The foliage along the avenues of approach on which RED attacks is sparse. The weather is good, and the base case is defined by current, albeit low-end, force capabilities for the RED, GREEN, and BLUE forces.

Situation Assessment

The survival of the enclave hinges on the attrition of the RED forces to a point at which they can no longer pose a threat without reinforcement. We determined that this would establish a success criterion that required the BLUE force to repulse the RED force while suffering no more

than 25 percent attrition. The mission of the RED force is to seize the enclave with at least one-third of its mounted force intact so it can reconsolidate in the enclave and repel any counterattack conducted by remnants of the GREEN/BLUE defense force. Thus, to be successful, BLUE would need to lose no more than one-quarter of its force while destroying at least two-thirds of the RED force.

The base case results for the Defense of an Allied Enclave are shown in Table 2.2. These results are similar to the attrition that the Chechens inflicted on the Russian forces that were attempting to seize the Chechen capital, Grozny, in 1994.[5]

Table 2.2

Supporting an Allied Enclave: Base Case Results

Systems	Start	End	Percent Survived	Percent Total Force Surviving
BLUE				
HMMWV-TOW	4	0	0	
HMMWV-Scout	6	2	33	
Machine gunner	20	12	60	47
Dragon gunner	30	12	60	
Rifleman/law	40	20	50	
Grenadier/Law	40	20	50	
RED				
T-72	50	23	46	39
BMP-2	40	12	39	

Source: RAND analysis.

Figure 2.7 shows the performance of the BLUE/GREEN base case forces as a filled-in square. About 52 percent of the BLUE/GREEN force survive, and it kills about 55 of the attacking RED mechanized forces.

[5]See, for example, Grau, 1995.

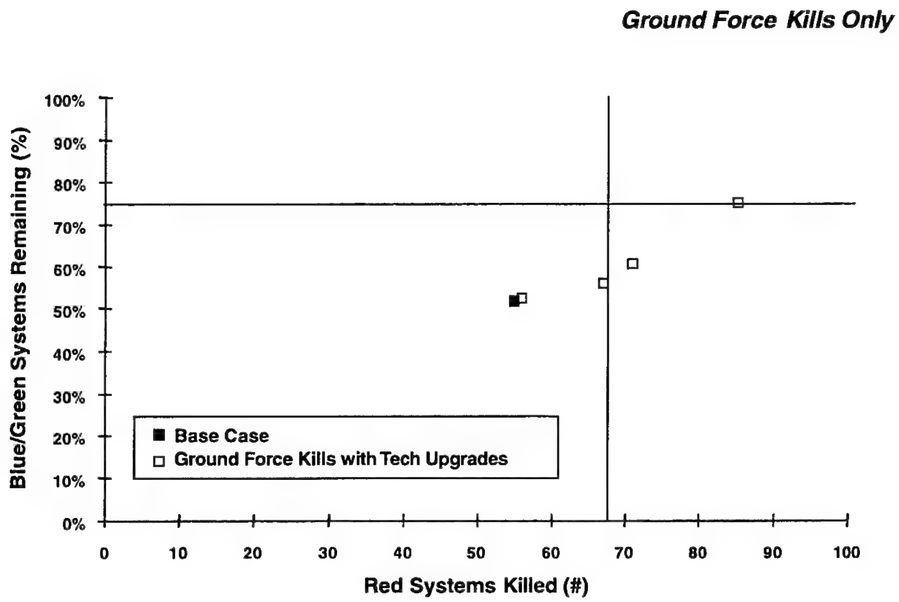


Figure 2.7—Supporting an Allied Enclave: Force Performance When Ground Force Capability Is Enhanced

The open squares that are up and to the right of the base case depict the performance of the force when it has been given enhanced engagement capability. The upgraded force closest to the base case in capabilities had systems with the capability to engage targets in 87.5 percent of the engagement time needed by the systems used by the base case force. The next points represent upgraded forces that took only 75, 50, and 25 percent of the time it took for the base case force systems to engage a new target. The systems in the most capable of the upgraded forces (the point farthest to the right on the chart) are able to engage a new target in essentially zero time. This improved target engagement time can be thought of as a surrogate for improved sensor, cueing, or C4I capability for the BLUE/GREEN forces.

As previously reported, improving the capability of the ground force makes the BLUE/GREEN forces more lethal, as would be expected. However, enhancing the ground force engagement capability does not have as pronounced an effect on the BLUE/GREEN survivability. In fact, the success criterion is reached only in the case that is probably the least achievable, where it takes almost zero time to acquire a new target.

Figure 2.8 shows the performance of the BLUE/GREEN forces when notional close support has been applied to counter the attacking forces. The analysis was carried out by parametrically removing the *most valuable* RED forces from the vignette in order of priority before the battle was joined. The point closest to the base case had 10 armored fighting vehicles (AFVs) removed from the main RED axis of attack. The next five points up and to the left on the graph represent the removal of 20, 30, 40, 50, and 60 AFVs from the RED force before the battle commences. In the first four cases, the AFVs were removed from the main RED axis of attack. The last 10 and 20 AFVs removed were taken from the supporting attacks.

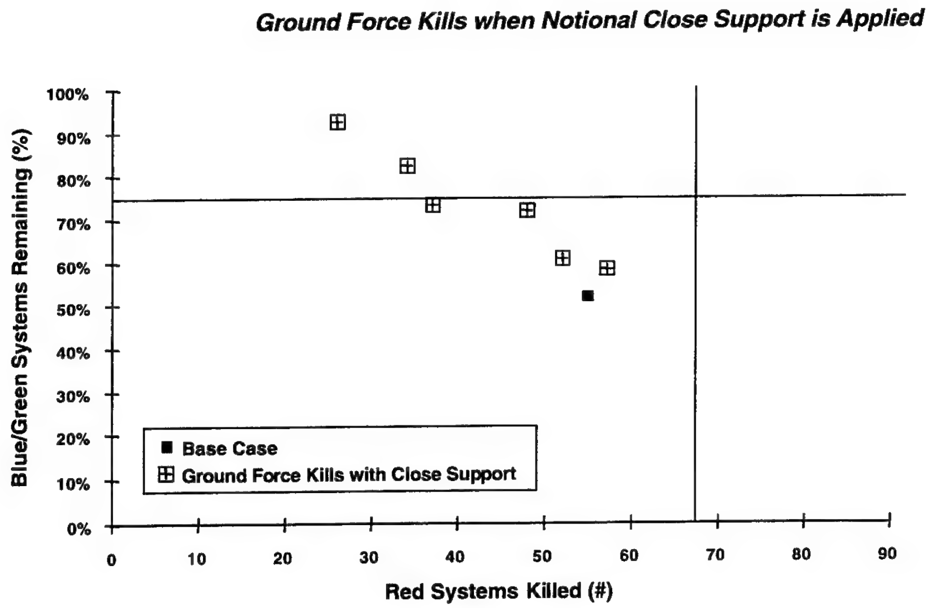


Figure 2.8 – Supporting an Allied Enclave: Ground Force Performance When Notional Close Support Is Applied

The interesting result that emerges from this case (and the subsequent cases) is that although the surrogate close support dramatically improves the BLUE/GREEN survivability, the ground forces kill fewer and fewer RED systems. This is due in part to the fact that there are fewer RED systems for the ground forces to engage. In addition, the BLUE/GREEN forces were initially arrayed so that the majority opposed the RED main axis of attack. Since the first four cases simulated close support by removing targets from the RED main axis of attack, the BLUE/GREEN forces were in essence misallocated. This is not an unrealistic representation. Light forces do not have a lot of firepower, and an additional, often over-looked characteristic is that light forces have even less tactical mobility. In the course of a real engagement, as the close support reduced the RED main axis of attack, the BLUE/GREEN forces would not have the mobility to reposition their firepower in real time.

Figure 2.9 shows the graph of the ground force kills added to the RED forces removed to simulate close support kills. The first notional close support case satisfies the lethality success criterion, but it takes the removal of 40 AFVs to satisfy the BLUE/GREEN survivability success criterion.

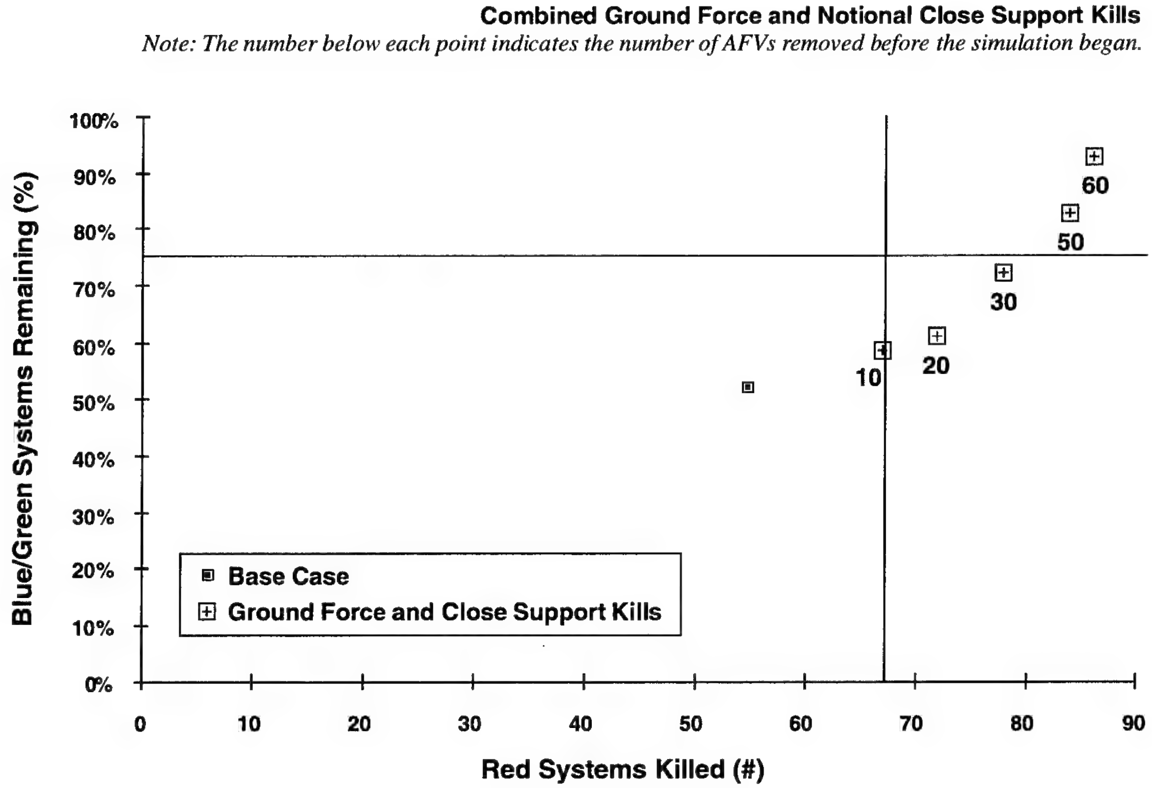


Figure 2.9—Supporting an Allied Enclave: Combined Close Support and Ground Force Effects on the Battle

Observations on Future Close Support Needs and Desirable System Characteristics

Advanced artillery faces a number of employment challenges in the urban environment. The urban environment provides limited locations from which to employ advanced artillery. The attackers probably have sufficient familiarity with the enclave to know the places—e.g., parks, schoolyards, and parking lots—from which artillery can be employed. The weapons and their ammunition stores provide lucrative targets for counterbattery fire.

The use of an external firebase concept also has some inherent limitations. The attacking targets must be serviced in all directions around the enclave. The urban area may mask some targets and prevent them from being fired upon from an external firebase. In addition, the firebase is itself an enclave, susceptible to attack.

The right battlefield information can importantly improve close support system performance. These situation assessments suggested that there is an important payoff for battlefield information. Given that the study team's analysis was oriented to finding "firepower" answers, these "information" insights are all the more notable. To explore this finding further, the study team conducted a series of excursions to examine the role of information in this battle to illuminate the issue of just how much advantage could be taken of its potential value. Figure 2.10

represents the allocation of the 30 BLUE medium anti-tank weapons to the likely avenues of enemy approach in the base case, based on the preliminary assessment of the characteristics of the avenues of approach.

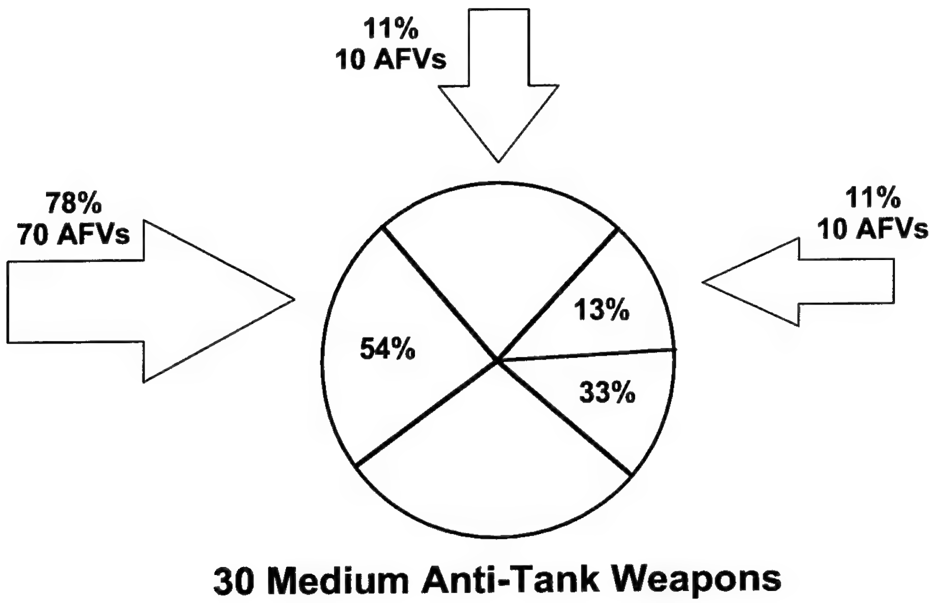


Figure 2.10—Initial Force Allocations

The arrows represent the allocation of attacking AFVs: 78 percent to the main attack from the west, and 11 percent to each of the two supporting attacks from the north and northeast.

Figure 2.11 represents how the BLUE/GREEN commander would have allocated his medium anti-tanks weapons had he had access to perfect information with respect to RED's attack allocation.

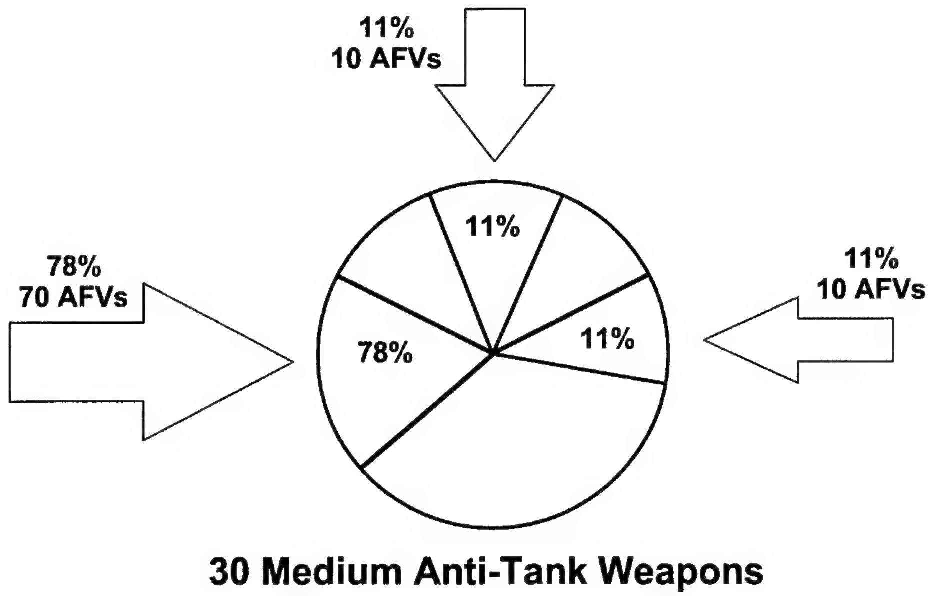


Figure 2.11—Initial Force Allocation with Perfect Information Concerning Enemy Intentions

Figure 2.12 depicts the final allocation of attacking RED forces after 60 AFVs were removed by notional close support. The BLUE anti-tank weapons were allocated with no prior information concerning RED's attack intentions and no information concerning the planned close support attacks or their results. This clearly shows that in the absence of these pieces of combat information, the medium anti-tank weapons were badly misallocated.

Figure 2.13 shows how the BLUE commander would allocate his anti-tank weapons if he had perfect initial information concerning the RED attack intentions and perfect prediction of the attrition caused by close support.

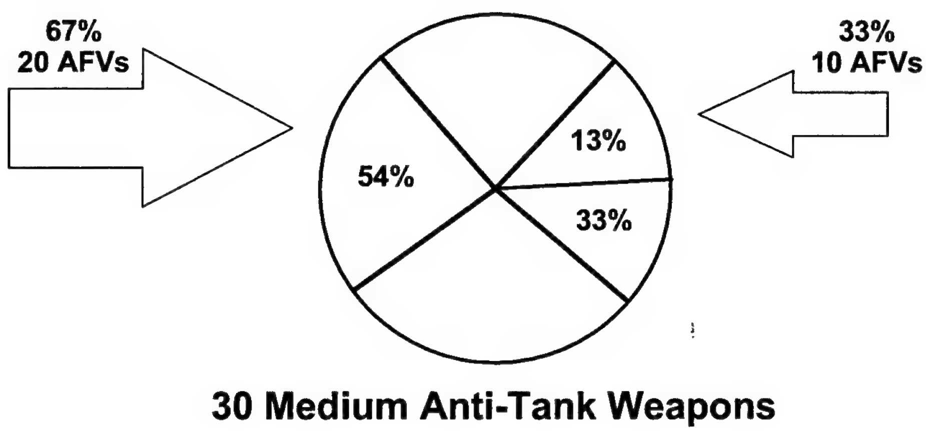


Figure 2.12—Force Allocation After Notional Close Support Has Been Applied, But With No Information Concerning Enemy Intentions or Close Support Results

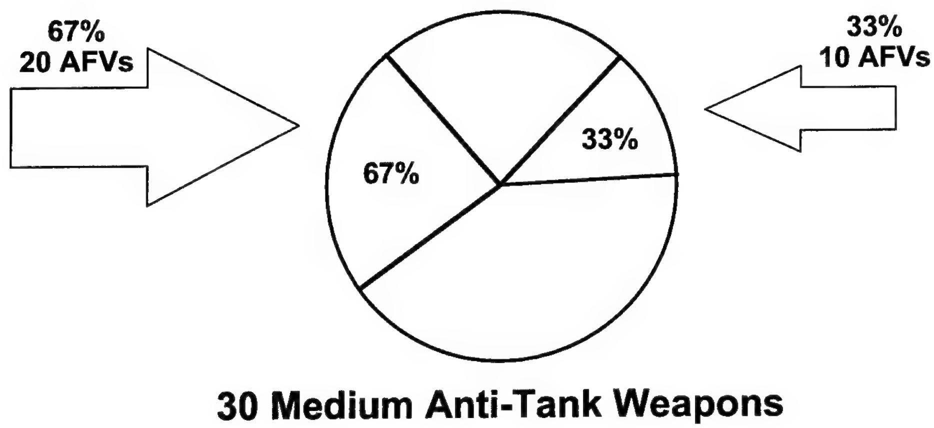


Figure 2.13 – Force Allocation with Perfect Information Concerning Enemy Attack Intentions and Close Support Results

It seems unlikely that a commander would be so confident in the quality of his intelligence information and the predicted contribution of the close support that he would knowingly misalign his forces to concentrate on the support attacks and count on the close support to counter the main attack. This is undoubtedly true regardless of the close support system involved. However, the ground commander would probably be most confident in his own, organic advanced artillery, somewhat less confident in attack helicopters, and even less confident in the availability of the other service's fixed-wing close support. This philosophic debate is beyond the scope of this research. However, Figure 2.14 does show the difference in BLUE performance that could result if the sensing and C4I systems were sufficiently developed so that a BLUE commander was willing to depend upon the battlefield information they provided.

Figure 2.14 compares the results of the notional close support runs with no changes to the allocation of firepower by the supported ground force, to cases in which the combat firepower of the ground force was reallocated based on perfect knowledge of what effect the notional close support had on RED in each application.

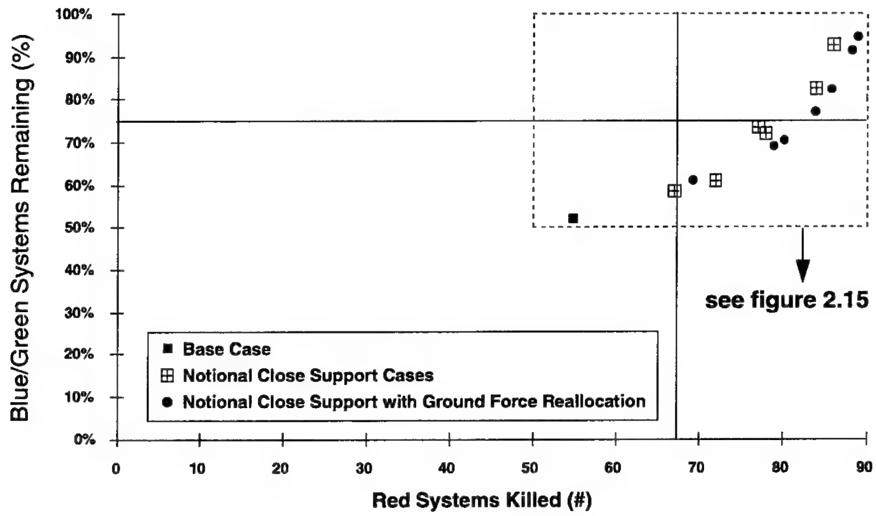


Figure 2.14—The Value of Varying Amounts of Battlefield Information

In general, we see a translation of the force performance measures (RED attrition, BLUE survivability) moving to the right and up on the graph, reflecting on improvement with respect to both measures of performance.

Figure 2.15 shows the change in each of the notional close support application cases after perfect reallocation of the ground force. Since every case results in a sufficient destruction of RED forces, this figure focuses on BLUE survival. The length of the individual bars shows the value of perfect information in each case. In general, in terms of BLUE survivability, information is more valuable when less firepower is available.

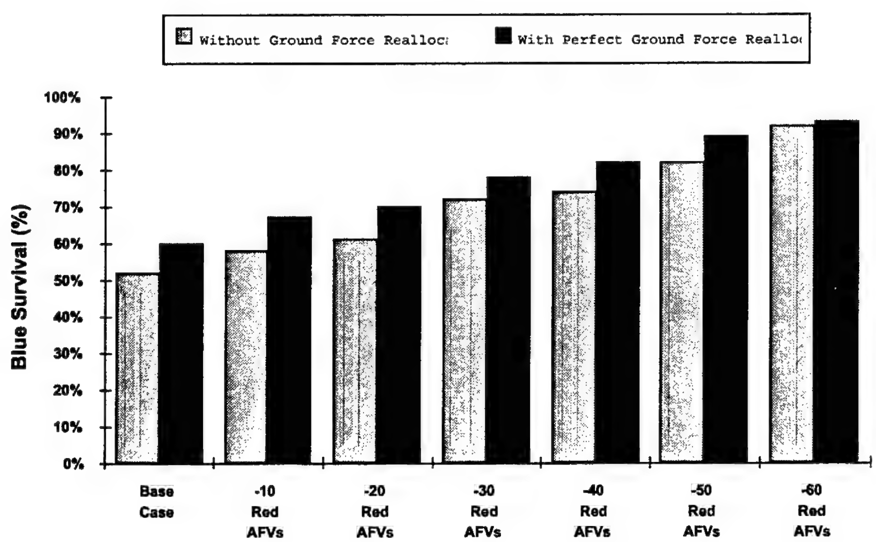


Figure 2.15—Improvement in BLUE Survivability Resulting from the Perfect Reallocation of Ground Force Firepower in Response to the Effects of Close Support

Fixed-wing aircraft or attack helicopters must provide a high AFV kill rate. The notional close support removed as many as 60 AFVs from the attack. To kill this many targets from the confined air space in the vicinity of an enclave will require multiple AFV kills per pass and multiple passes per sortie.

Better target-pattern/munitions-pattern matching would improve fixed-wing capabilities. Table 2.3 shows the munitions patterns used in the JANUS simulation for seven cases in which the F-16s delivered sensor-fuzed weapons (SFWs) against the RED forces. The targets were company-sized formations of armored vehicles. In the first five cases, the attacks were made against moving targets; cases 6 and 7 simulated attacks against the company-sized target arrays prior to the start of their assault (stationary columns in assembly areas).

Table 2.3

Fixed-Wing Systems Using SFW Against Moving (Cases 1-5) and Stationary (Cases 6-7) Target Arrays

Case	Munitions Pattern
Case 1	Base-case SFW footprint, 10 BLU-108s per TMD
Case 2	4 x base-case SFW footprint, 10 BLU-108s per TMD
Case 3	16 x base-case SFW footprint, 10 BLU-108s per TMD
Case 4	16 x base-case SFW footprint, 5 BLU-108s per TMD
Case 5	16 x base-case SFW footprint, 5 BLU-108s per TMD, 50% improved Pk
Case 6	Base-case SFW footprint, 10 BLU-108s per TMD
Case 7	4 x base-case SFW footprint, 10 BLU-108s per TMD

Source: RAND analysis.

The results in Figure 2.16 clearly show that the effectiveness of fixed-wing-delivered SFWs against moving targets is sensitive to the footprint size of the individual sub-munitions. This is caused by the match or mismatch between the configuration (target pattern) that the targets present and the munitions pattern, or footprint. SFW effectiveness is constrained by the limited ability of the aircraft to align the long, narrow SFW footprint with the linear axis of the target vehicle arrays.

Since this weapon-pattern/target-pattern matching is one of the primary determinants of SFW effectiveness, the assessments that result from our analysis of SFW capabilities are generally more pessimistic than those found in most studies. This is because most analyses typically do not model the entire battle situation or aircraft flight paths. They rely instead on assumptions about how well the attack axis is aligned with the target axis. In general, these assumptions are more favorable to fixed-wing capabilities than our analysis found was warranted in the battle situations we simulated.

To explore the munitions characteristics that could improve this situation, we examined wider SFW footprints. The evolution of the cases from 1 to 3 represents improvement in sensor technology on the Skeet sub-munitions without any payload cost. Case 4 represents a 50 percent

payload cost for the sensor technology and deployment mechanism in the TMD, and case 5 represents the recovery of some of the cost in case 4 in the form of a hypothetical 50 percent increase in Pk.

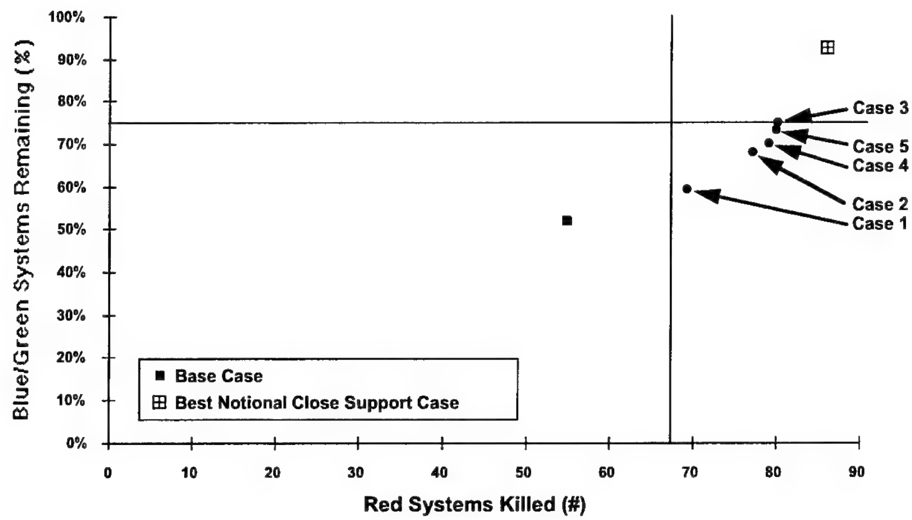


Figure 2.16—Supporting an Allied Enclave: Results of Fixed-Wing Systems Using SFW Against Moving Target Arrays

Note that the most realistic case simulated (case 5) still leaves us somewhat below the predefined success criterion for the vignette. As a result, we also explored a change in the employment of the F-16s to increase the effect of their attacks. Figure 2.17 shows the JANUS results for cases 6 and 7, in which F-16s deliver the SFW against the stationary target arrays, attacking the vehicle arrays before they have begun their movement to contact.

The results show that when the target arrays are stationary, an improvement in the sub-munition's sensor technology that would result in a fourfold increase in the SFW footprint size would allow the fixed-wing attacks to meet the success criterion for the vignette. This is attributable to better matching of the weapons pattern to the size and spacing of the target elements and to the lack of movement during the prior-to-movement posture.[6] These cases, however, also imply the need for an information system that is capable of identifying the targets in such a posture and focusing the airpower on the opportunity. There are also rules of engagement and fratricide issues that must be addressed if such wide-footprint munitions are to be employed in close support.

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[6] In addition to sensor improvements, aerodynamic forces may be needed to disperse the sub-munitions away from the attack axis to widen the pattern, as is typically done with mini-missile sub-munitions.

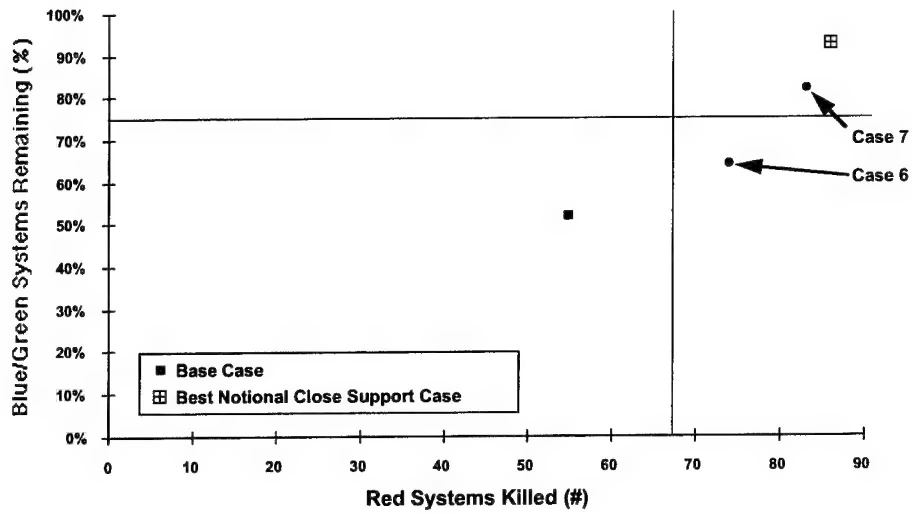

Figure 2.17—Supporting an Allied Enclave: Results of Fixed-Wing Systems Using SFW Against Stationary Target Arrays

This potential lethality improvement due to footprint size (actually, to better matching of the munitions' footprint with the target's footprint) occurs because of the typical armored target configurations that occur in battle. In mechanized combat, particularly in the defensive battles where close support may be most critical to battle outcomes, targets present themselves in two general configurations over the course of the battle.

The first is a small formation of platoon to company size (three to 10 vehicles), in attack formation, as illustrated in Figure 2.18. Vehicle spacing is influenced by terrain but is on the order of 100 meters, and the vehicles are arrayed in a line-abreast configuration parallel to the line of defenders and move to contact in a direction perpendicular to the line of defenders. While there are multiple variations of these formations on the battlefield at any given time, and they could be addressed as larger target aggregations for fleeting periods of time, the most consistent target that presents itself is the smaller unit, because it is the fundamental fighting unit on the battlefield. These targets are present throughout the course of the battle and form the majority of targets that must be serviced by systems providing close support.

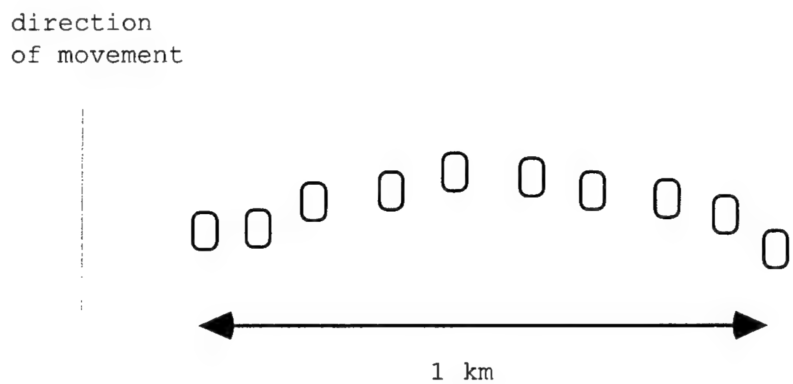

Figure 2.18–Platoon- and Company-Sized Formations in Mechanized Combat (Battlefield Depiction from the JANUS Combat Simulation)

The second target configuration (Figure 2.19) is a larger, multiple-company or battalion-sized formation (20 to 30 vehicles) intended to effect a tactical breakthrough. Vehicle spacing is 50 to 100 meters in trail, and the formation moves in a line toward the defenders, as a road-march formation does. This target presents itself infrequently over the course of the tactical battle (once or twice during the 60-minute combat period that characterizes each assault).[7] This formation is, of course, a very important target to counter and can be viewed as the primary reason additional close support firepower is needed during the tactical battle.[8]

[7]There is also a distinct difference in the exposure profiles of these two classes of targets. While the fixing attack formations appear all throughout the battle, the appearance of the breakthrough target can not be anticipated with a high degree of confidence. This means that close support systems must insure that they are in a position and status that allow them to respond when the breakthrough attempt does take place. As we have pointed out in the previous discussion of advanced artillery systems, this need to hold some part of the force at the ready can change the way close support systems are employed.

[8]The relative importance of target formations in attack versus road march is still to be determined in our scenario work, but we believe the balance will tip toward deeper road-march interdiction (as opposed to the requirement for "close support" in the strictest sense) due to expected U.S. information dominance and firepower flexibility.

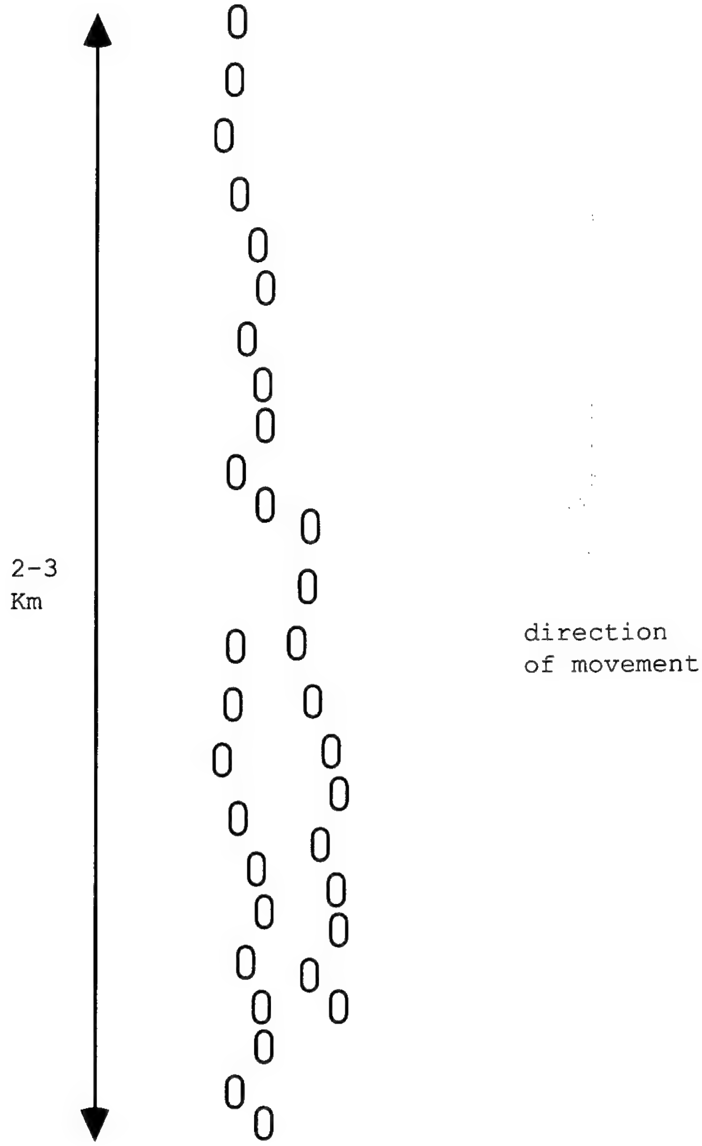

Figure 2.19 – Battalion-Sized Breakthrough Formations in Mechanized Combat (Battlefield Depiction from the JANUS Combat Simulation)

Doctrinally, both of these targets are long (.3 to 3 km) and narrow (not much more than a few vehicles across the narrow dimension). During movement on actual terrain, the smaller target tends to be more cluster-like and the breakthrough force tends to "snake" along lines of communication and around obstacles. Thus, even if attacking close support systems could fully exercise a choice of the best attack axis, neither target presents an ideal linear array. The effects of these target configurations stress the ability of the munitions to efficiently regard each target element (vehicle) and dictate munitions characteristics for effective employment.

Three general approaches are available: scattering unguided sub-munitions, using extended range sub-munitions with sensor fuzing, and using homing (sub-)munitions (e.g., laser designated by a forward observer or terminally guided sub-munitions [TGSMs]). A comparison

of these concepts when employing equal payload dispensers of equally lethal[9] sub-munitions against the two close support target configurations is shown in Figure 2.20.

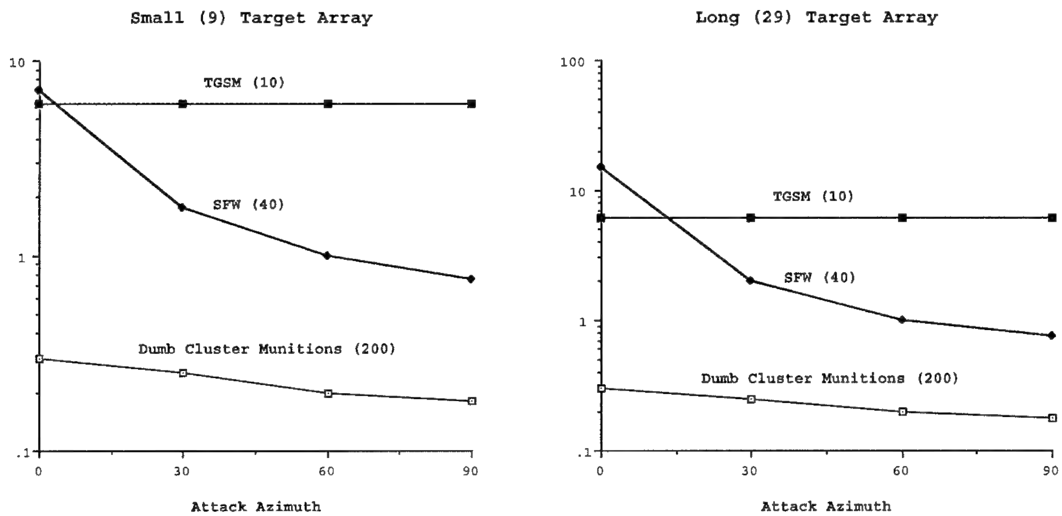

Figure 2.20—Comparison of Three Munitions Concepts

The left panel of the figure plots the expected kills against the smaller target as a function of the angle between the missile/aircraft attack axis and the long axis of the target; the right panel does the same for the larger breakthrough formation. In both instances, the "smart" sub-munitions concepts prove to be a dominant approach for ideal attack geometry, hitting[10] about 10 vehicles per engagement in comparison to no more than .5 vehicles for the unguided sub-munitions concept. The order of magnitude difference in effectiveness means that the "smart sub-munitions" concepts could cost 10 times as much as the unguided sub-munitions concept and still be as cost-effective in terms of hits per dollar.[11] This tracks roughly with ballpark costs of $20,000 for the unguided sub-munitions dispensers and $200,000 for the SFW sub-munitions concepts.[12] When it is not possible to match the attack axis with the target axis, as is often the case in combat, the SFW concept with its limited cross-range capability degrades in effectiveness by up to an order of magnitude (expected hits dropping from about 10 to only one vehicle in the extreme case). While the unguided sub munitions concept degrades in a similar manner (arguing that the SFW concept and the unguided sub-munitions concept remain comparably cost-effective in the more trying situation), the TGSM concept suffers no comparable degradation. In the

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[9]The sub-munitions have been assumed to be equally effective given a hit for purposes of even-handed comparison.

[10]For purposes of first-order assessments, we have assumed that the warheads for each of the types of sub-munitions are all equally capable against the targets and, for the two different types of "smart" sub-munitions, equally likely to hit the target if it is within their sensor's field of view and the sub-munition's range.

[11]Combat utility (impact on combat outcomes) is another matter. Tactical-level battle simulations like JANUS have shown that killing rates of one-half vehicle per engagement do not result in a sufficient level of kills to have any effect on combat outcomes during the 60 minutes or so that it takes for a battalion battle to run its course, because attacks can not be conducted rapidly enough during that period.

[12]Costs are representative of the CBU-87 and CBU-97, as reported in *Air-to-Surface Munitions Handbook*, 1992.

extreme, the TGSM concept is an order of magnitude more effective than the SFW concept. This argues that this concept could cost substantially more and still be the preferred approach. IR versions of these sub-munitions should be producible for roughly the same costs as the Hellfire or Stinger missile (roughly $40,000) due to the rough similarity in technology, so a cluster weapon of 10 sub-munitions such as we used in our example would cost approximately $400,000—twice the cost of the cluster weapon using the SFW concept. Given that the effectiveness differential is a factor of two or greater with target/attack misalignments of only 20 degrees (for the more demanding larger target), the higher unit costs of the TGSM concept would seem warranted.

Issues and Desirable Characteristics Based on These Combat Vignettes

Fixed-Wing Issues: How Can Fixed-Wing Systems Engage More Effectively (With Faster Kill Rate) Within the Attrition Management Window?

From the results of this scenario (and also the analysis of the Armored Force Meeting Engagement vignette that appears in Section 5) and given the restricted airspace around the enclave and the potential attrition of fixed-wing assets, a desirable way to provide the needed close support is the standoff, lofted delivery of SFWs. The multiple-kills-per-pass capability could provide the needed lethality in the required time. However, as indicated by the analysis of this combat situation, improvements to weapons footprints, particularly those associated with TGSMs, can allow much faster kill rates and better robustness against target configuration than are currently available.

Attack-Helicopter Issues: What Munitions and Sensor Characteristics Best Match Rotary-Wing Engagement Profiles?

In our simulation results for the Escort of a Humanitarian Convoy, four helicopters that arrived on the scene 10 minutes after the start of the ambush conducted a pattern search centered on the ambush site. Within 60 minutes of the start of the ambush, they had detected 23 of 24 members of the ambush team egressing from the ambush. This implies that present sensor technology satisfies the close support requirement after the ambush. However, it must be noted that the ambush team was withdrawing through unpopulated countryside, and the requirement to distinguish the enemy from innocent noncombatants was not required. Although we did not simulate the case where the helicopters escorted the convoy, they undoubtedly would have killed all of the team in the first few minutes after the ambush. However, such an approach may be only partially effective in the long run and will not preclude the loss of the convoy being escorted.

These conditions combine to argue that the most effective strategy is to use sensors that can detect the location of the ambush team before the event so that the ambush can be avoided. This

means that instead of seeking ways to allow helicopters to engage the enemy during the ambush, the focus should be on ways to detect the ambush team and how to handle that force once it is located and the ambush avoided. Helicopters have desirable characteristics that may importantly aid this strategy, such as elevated observation positions, the ability to hover, and a speed regime that is compatible with the supported unit.

Sensors, Cueing, and Fire Control Issues: What Contribution Would a Tactical Surveillance, Targeting, and Reconnaissance System Make to Battle Outcomes?

The analysis of the Escort of a Humanitarian Convoy and Support for an Allied Enclave vignettes provided some valuable insights concerning the desirable characteristics of tactical-battlefield information-gathering systems. The consensus is that the best strategy for defeating an ambush is to avoid it. This strategy depends on battlefield information. The Support for an Allied Enclave analysis explicitly shows the potential contribution of information systems. A number of emerging technologies may help us cope with ambushes. Computer processing power continues to increase exponentially and may enable radar imaging that recognizes the weapons in the hands of the members of the ambush team or the IR signature of the team members themselves. As we previously observed, finding information-based answers while looking for firepower answers makes the insights concerning battlefield information considerations all the more impressive. For further discussion of sensors, cueing, and fire control issues, see Section 3.

3. Supporting Light Infantry

We found that a common characteristic of the types of battlefield situations that U.S. forces have encountered in the recent past (since Vietnam) has been the dependence on light infantry forces. Our review of recent combat history showed that these battlefield situations occur because light infantry forces are often the only forces appropriate for the terrain (e.g., Panama) or because light infantry forces can be rapidly deployed in a crisis (e.g., Desert Shield).[1] Such forces may require close support to provide additional firepower and to offset their lack of tactical mobility.

Supporting light infantry poses problems that are very different from those explored so exhaustively for mechanized combat. Among the important differences are a more limited ability to effectively shape the close battle through interdiction and deep fires, the generally closer proximity of adversary forces in the close battle, target acquisition and identification difficulties, greater potential for collateral damage and casualties, fratricide, and the need for extremely short response times.

We have selected two vignettes for analysis as representative of these battle situations:

- Small Unit Infantry Assault
- Small Unit Infantry Patrol

Small Unit Infantry Assault

Small unit infantry assaults are part of a class of direct action operations that encompass short-duration strikes and other small-scale offensive actions taken by Special Operations Forces (SOFs) or other light forces to seize, damage, or destroy a specific target.

Small unit assault operations are normally limited in scope and duration and have a preplanned ex-filtration. Typically the force is attacking a target important to attaining or maintaining the political and military initiative (capture of the adversary's leadership, neutralizing a weapon of mass destruction, disabling an air defense system).[2] Such operations are designed to achieve specific, well-defined, and often time-sensitive results of strategic or operational significance. Normally the goal of the action is to achieve a specific objective rather than gaining or holding terrain. The target may be located in a variety of environments, such as a military complex, an industrial facility, an insurgent base camp, or a terrorist training facility. The employment of a small SOF team—as opposed to some other attack asset, such as missiles, artillery, or air

[1] Among the contingency operations we considered were: Mayaquez Operation (SEA), El Dorado Canyon (Libya), Urgent Fury (Grenada Rescue), Just Cause (Panama), Desert Shield/Storm (SWA), Provide Comfort (Kurds in Iraq), Restore Hope (Somalia), Able Sentry (Macedonia), Uphold Democracy (Haiti), and Deny Overflight (Bosnia).

[2] From U.S. Army FM 100-5, *Operations,* June 1993, page 13-8.

bombardment—is due to some unique feature of the target, terrain, or situation. Opposition leaders may be more valuable politically if captured alive; the use of aircraft could negate the element of surprise, allowing time for the target to be moved or hidden. A missile or artillery attack will probably not insure that we have successfully neutralized a weapon of mass destruction. Failure, or lack of confidence in success, could have equally disastrous implications.

These operations are normally undertaken beyond the range of ground-based tactical weapons systems, outside of the area of influence of conventional military forces, under the control of the U.S. chain of command, and are not dependent upon popular support of the indigenous population.[3]

Small unit assaults can be characterized by three main phases. The first is the preparation and ingress phase (which may last hours or days depending on how far the force has to move to reach the action site and on the kind of transport available to it). This is followed by an intense and short engagement phase likely lasting minutes to several hours. A planned and rapidly executed egress completes the operation. Although we took the ingress and egress phases into account in our analysis, we did not simulate them.

JANUS Vignette—Small Unit Assault

We have developed a prototypical combat situation representative of small unit assaults. As shown in Figure 3.1, the locale is a military complex and the action could be associated with the major contingency in the Far East theater-level scenario. This dictates a stealthy/surprise insertion of a BLUE assault force, which is accomplished by helicopter far enough away from the target to avoid detection.

The immediate RED security force is small enough to give the assault force a high probability of rapidly achieving numerical and firepower superiority, but this advantage is temporary in nature and thus limited to roughly the time it takes for the team to conduct the mission if there are no significant delays. The assault force's objective is to neutralize a high-priority apparatus located in one of several possible secure storage facilities within the complex. For the purposes of the vignette, the success criterion is that designated members of the team must close with the storage facility containing the apparatus with enough time to breach the facility and destroy the apparatus. The general disposition of forces is shown in Figure 3.1.

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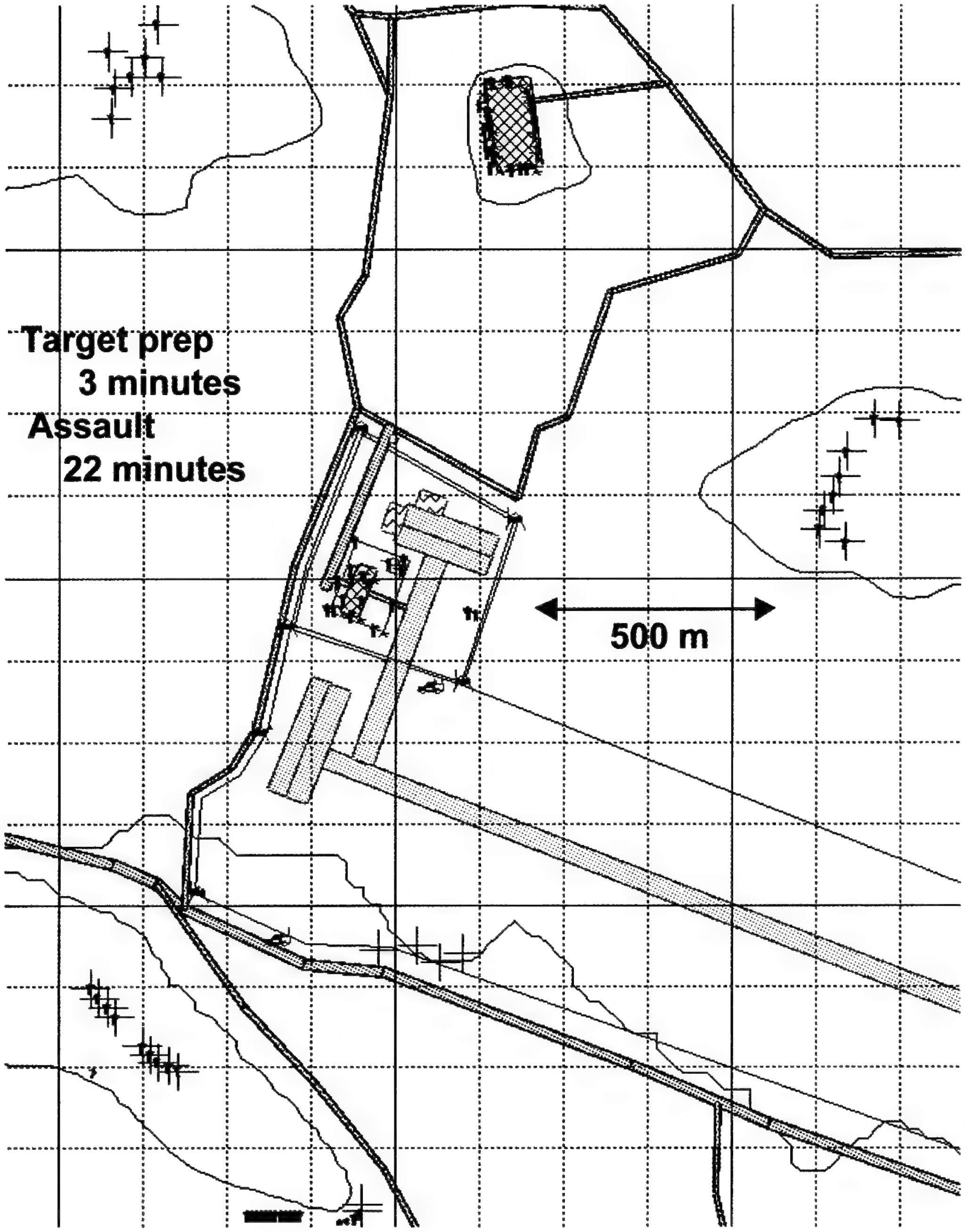
[3] This description is taken from U.S. Army FM 31-20, *Special Forces Operations*, 1990, pages 3-3 and 11-1/2.



Source: RAND analysis

Figure 3.1—Small Unit Infantry Assault: Initial Force Deployments

This vignette is composed of a BLUE task-organized SOF of platoon size attempting to recover a person or device from a heavily guarded airfield and adjacent compound. Specifically, the BLUE team is organized into three support/security teams positioned on high ground overlooking the compound to the northwest, northeast, and south, and the assault team, which is initially located south of the compound in a covered and concealed assault position. The RED force consists of a 32-man security guard detail; an immediate reaction force (IRF) consisting of 36 light infantry troops located in a nearby barracks; and a mounted quick reaction force (QRF) consisting of a

company of light infantry, 15 armored personnel carriers (APCs), and five tanks, all located in a cantonment area approximately 5 kilometers from the airfield.

The terrain on which the vignette is set is generally flat and bare of vegetation where the airfield is located, and is surrounded by moderately foliated hills. The weather is poor (by design of the assault force), and the operation is conducted in the predawn hours of the day.

Situation Assessment

The success of the assaulting force hinges on the survival of the 12-man assault team. It must penetrate the critical building located in the interior compound of the airfield. For the purposes of this analysis, we assumed that 75 percent of the assault team must survive to accomplish its mission once the team members have reached the critical building. The losses inflicted on RED are not considered to be an important part of the success criterion for BLUE.

The engagement phase begins when the team arrives at the complex and initiates its operation. This phase takes about 30 minutes and ends with the capture or destruction of the apparatus before the team begins its withdrawal. This last phase, the withdrawal, is not currently modeled.

The base case attrition results, shown in Table 3.1, are disastrous. None of the BLUE assault team survives to penetrate the critical building. The six gun towers around the interior compound of the airfield and the forces in the IRF barracks inflict very high attrition on the assault team. In the base case, the BLUE force requires 3 minutes to destroy the QRF barracks and the six gun towers. This is entirely too slow. The need for additional fire support is quite evident.

Table 3.1

Small Unit Infantry Assault: Base Case Results

Systems	Start	End	Percent Survived	Percent Total Force Surviving
BLUE				
Assault team	12	0	0	0
RED				
Guards and IRF	68	61	89	89

Source: RAND analysis

Figure 3.2 is a graphic of the results of the small unit infantry assault. The filled-in square, which represents the base case, shows that the entire assault team is killed and fewer than 10 RED defenders are killed.

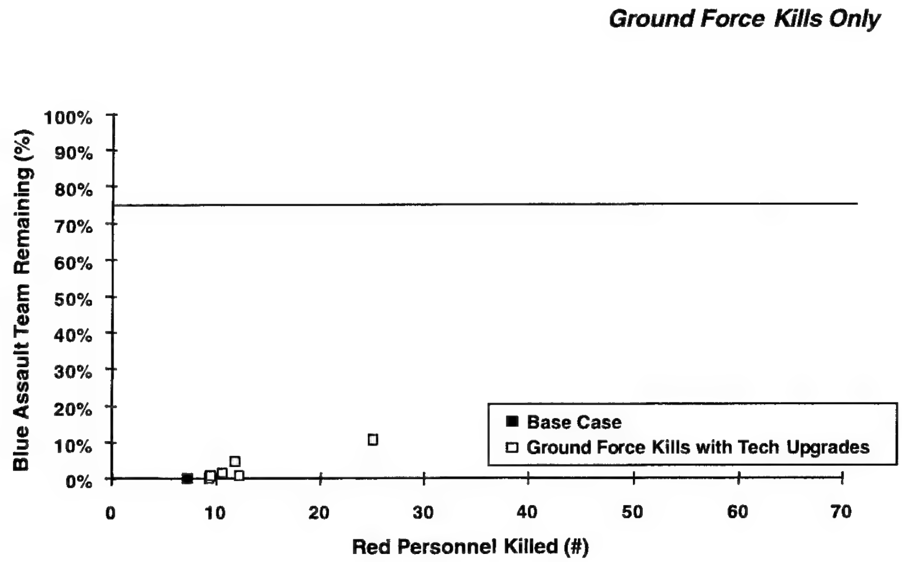


Figure 3.2—Small Unit Infantry Assault: Force Performance When Ground Force Capability Is Enhanced

In an attempt to achieve a more desirable outcome, the engagement capability of the BLUE assault force was enhanced. The upgraded force closest to the base case in capabilities had systems with the capability to engage targets in 87.5 percent of the engagement time needed by the systems used by the base case force. The next points represent upgraded forces that took only 75, 50, and 25 percent of the time it took for the base case force systems to engage a new target. The systems in the most capable of the upgraded forces (the point farthest to the right on the chart) are able to engage a new target in essentially zero time. It should be noted that dramatic improvement in the capability of the base force accomplishes very little in terms of enhancing the lethality and survivability of the assault force.

To further assess this scenario, we examined a range of notional close support capabilities. The analysis was conducted by removing the *most valuable* elements of the RED force in priority order. Figure 3.3 shows the effect of notional close support on the performance of the small unit assault force. The first notional close support point represents the destruction of two of the guard towers; the next point, four towers; the next point, six towers; and the final point, six towers and the QRF barracks. Here, unlike in the other vignettes, close support not only enhances the force's survivability but also improves its lethality.

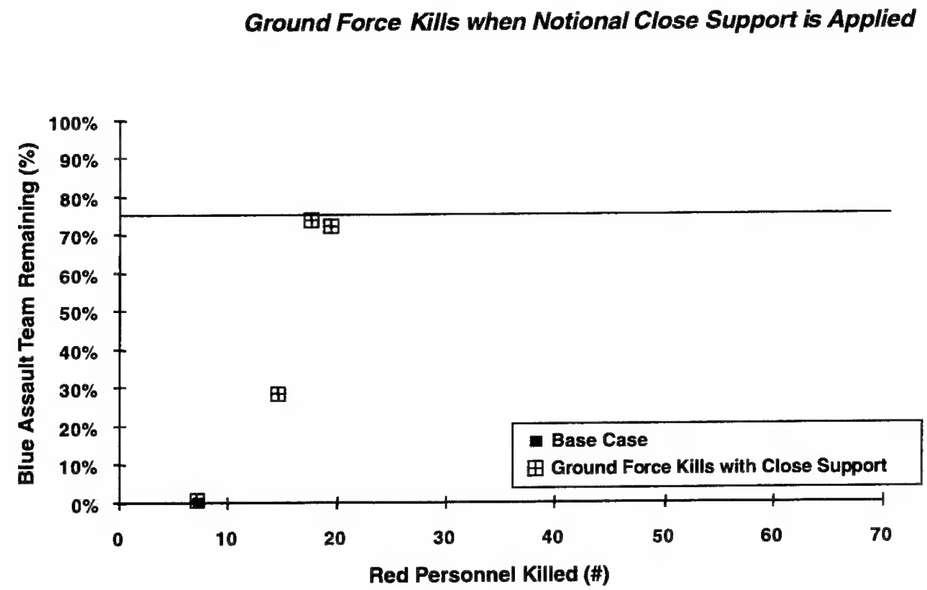


Figure 3.3—Small Unit Infantry Assault: Ground Force Performance When Notional Close Support Is Applied

This outcome results because the gun towers extract a terrible toll on the assault force, which survives much better when the towers are destroyed. However, destroying the towers does not kill a lot of RED forces and create a shortage of targets. It is only when the barracks and its 36-man contingent are destroyed that a shortage of targets occurs. This explains why the ground force kills slightly fewer RED forces when the barracks are destroyed by close support.

Figure 3.4 shows the contribution of close support to the performance of the assault force. These results show that in terms of the principal MOE, survivability, the assault force does about as well whether the six towers or the six towers plus the barracks are destroyed. In these last two close support cases, the assault force barely survives well enough to meet the success criterion.

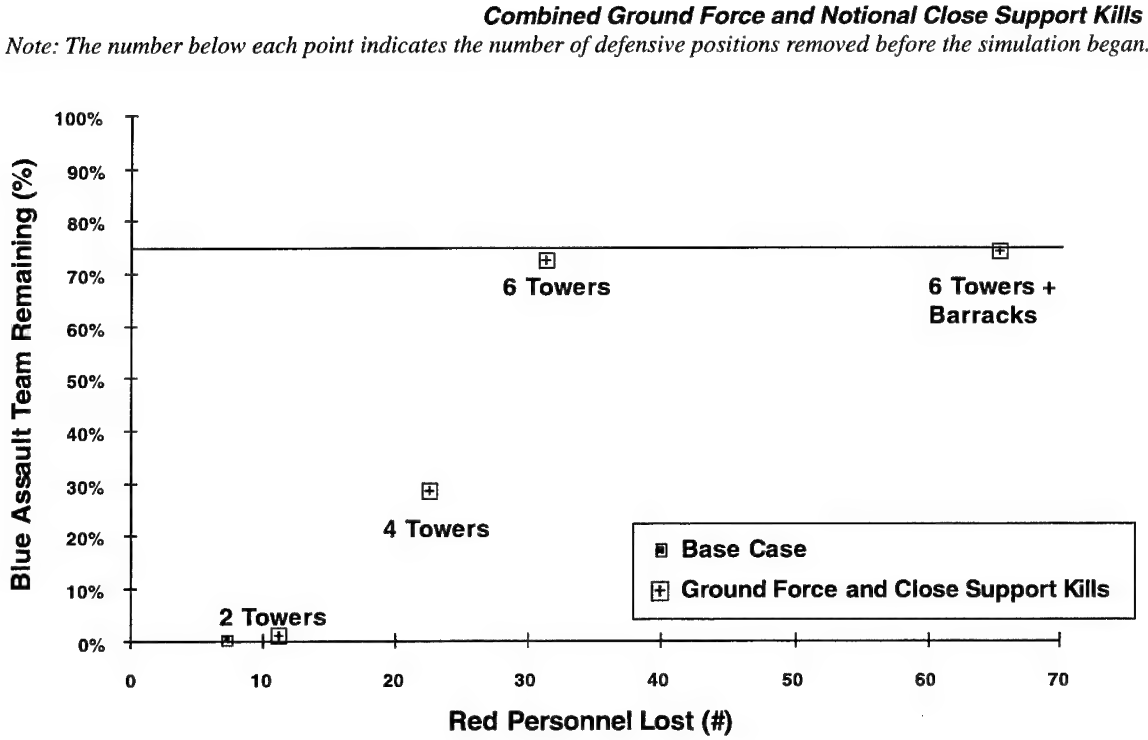


Figure 3.4—Small Unit Infantry Assault: Combined Close Support and Ground Force Effects on the Battle

Observations on Future Close Support Needs and Desirable System Characteristics

Close support is necessary for success. The analysis above demonstrates that substantial close support is essential to the success of the assault force. The study team then ran a series of cases to examine how the "notional" close support could be provided by the systems under consideration and to determine what characteristics were desirable in those systems. The attrition of the assault force when it is not supported by close support is prohibitively high, and the mission is not practical without additional firepower.

But in choosing how to provide this close support capability, an additional consideration is needed. Even the conceptual man-portable NLOS/FOG-M that we used in this scenario can not adequately solve the problem.[4] This system can not destroy the six towers quickly enough and it is not effective on the IRF barracks because of the limited lethality in its warhead. It also has limitations against the QRF because it has limited range and target acquisition difficulties. In short, due to the differing types of targets that must be handled by close support, the ground commander will need a mix of system types to meet the demands of this type of battle.

[4]The conceptual fiber-optic guided (NLOS/FOG-M) projectiles are mortar launched from six 60-mm mortar launchers (one per tower) located to the rear of each of the support/security teams. The NLOS/FOG-Ms are ripple-fired (three per mortar) 10 seconds apart to ensure destruction of the towers.

Mix of systems produced best results. Three cases were examined to explore joint-force packages:

- Laser-guided bombs (LGBs) delivered by F-117s to take out the barracks, plus NLOS/FOG-M launched from 60-mm mortars to take out six towers
- LGBs delivered by F-117s to take out the barracks, plus helicopter-launched Hellfire missiles to take out six towers
- LGBs delivered by F-117s to take out the barracks, plus NLOS/FOG-M launched from 60-mm mortars and helicopter-launched Hellfire missiles to take out six towers

Figure 3.5 shows that the three cases had similar results, all of which came close to satisfying the assault force survivability MOE and were very close to the "notional" close support results. It is interesting to note that both cases using simulated close support systems achieved results that were reasonably close to the notional results. The LGB plus NLOS/FOG-M achieved marginally better BLUE survivability because the attack was easy to coordinate. The assault support force fired the NLOS/FOG-M only after it had observed the LGB start the attack by destroying the IRF barracks. Neither NLOS/FOG-M nor the attack helicopters could take out all six towers alone. Because of the size of the IRF barracks and the lethality of the LGB against it, a fixed-wing system was needed in each of the mixes.

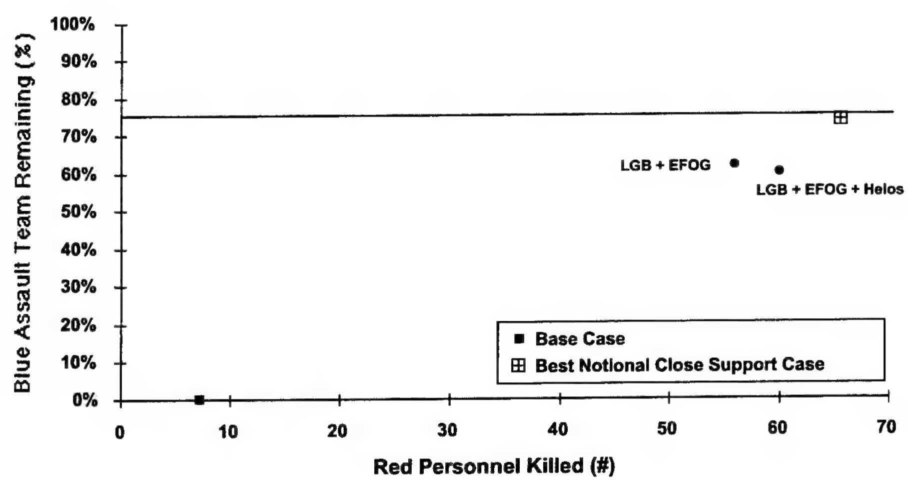


Figure 3.5—Small Unit Infantry Assault: Results of Joint Assets Providing Close Support

There is not much increase in assault force survivability when helicopters are added to fixed-wing and NLOS/FOG-M systems. One attack helicopter was flown to target the towers and one to engage the QRF and local air defense systems. Ground force designation of targets for attack helicopters was difficult due to geometry requirements for munitions delivery and limited maneuver space for helicopters. This condition would be exacerbated by the presence of local air defenses.

In the second case, where only helicopters engaged the six towers, a mean of 16 Hellfire missiles were fired in combination against the towers, the QRF, and the local air defense. However, as many as 23 Hellfire missiles were fired in some of the total of 30 runs. This exceeds the RAH-66's capacity for Hellfire missiles if only internal stores are used. If external hardpoints must be added to the RAH-66 airframe to accommodate the extra missiles, the ability of the RAH-66 to penetrate is degraded because of the enlarged radar cross-section. An alternative would be to use only internal stores but send more helicopters. More helicopters might increase the possibility of detection, but it is believed that the reduced signature will more than offset the disadvantage of more airframes.

In the third case, where helicopters and NLOS/FOG-M were both assigned the task of engaging the six towers, a mean of three Hellfire missiles were fired during the 30 runs. Since the maximum number of missiles fired in any of the runs was 16, two helicopters, carrying only internal stores of eight each, would suffice for the mission.

LGBs were needed in all cases to take out the IRF barracks and initiate the assault.

Both NLOS/FOG-M and attack helicopters are effective against the towers, but we found that neither package of these force components was able to service this target set sufficiently, and a larger contingent of either was problematic. This is because a larger insertion team would be required to pack in more NLOS/FOG-Ms, and more attack helicopters would be needed unless they carried external stores.

Additionally, attack helicopters are the most effective system for dealing with vehicular targets from the QRF and local air defenses. This is because the attack helicopters were able to acquire QRF vehicles well before they arrived at the scene of the assault battle.

A valid alternative mission for the attack helicopters would be to engage the QRF during the extraction phase of the mission (not simulated), so helicopters loaded only with internal stores should be added in both cases.

This small unit infantry assault is a very difficult mission even with effective close support, and it is an impossible mission without close support. However, it is a mission that is representative of the world in which future U.S. national defense needs must be satisfied.

Small Unit Infantry Patrol

Small unit patrols are an essential element of peacekeeping and humanitarian aid missions. They are typically composed of light infantry armed with man-portable weapons. Small unit patrolling was heavily employed in Grenada, Panama, Haiti, and Somalia and will play a large role in the Balkans operations

JANUS Vignette—Small Unit Infantry Patrol

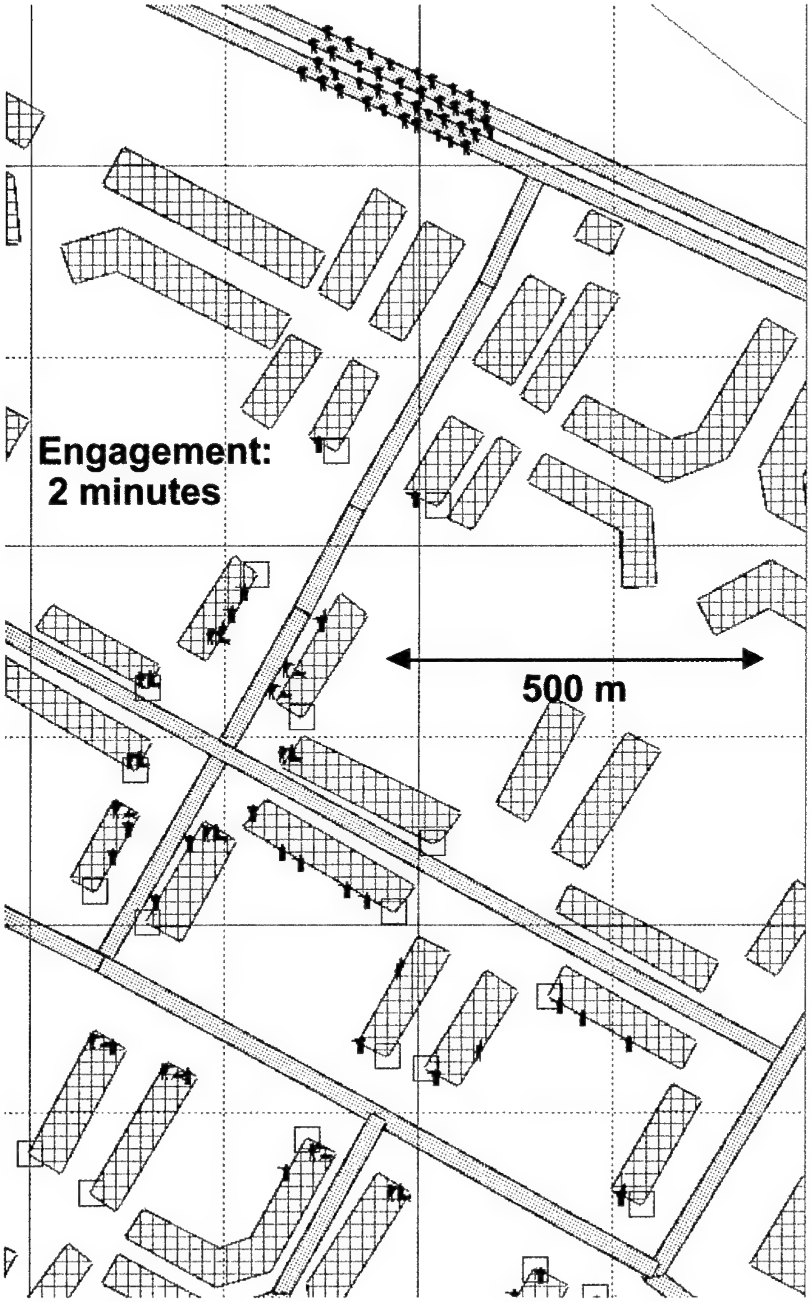
We chose to locate the peacekeeping contingency in the Balkans. This vignette is composed of a BLUE platoon-sized patrol of 40 light infantry returning from patrolling operations in an urban environment (see Figure 3.6).

Source: RAND analysis.

Figure 3.6—Small Unit Infantry Patrol: Urban Environment

The terrain on which the vignette is positioned is level and has multi-story buildings ranging from two to 10 stories. The primary kill zone for the ambush is on a street with 10-story buildings on both sides. The weather is good, and the base case is defined by current force capabilities for both RED and BLUE.

The RED force, shown in Figure 3.7, consists of 51 light, irregular infantry deployed in a deliberate ambush in positions in multi-story buildings along the BLUE patrol route at both near and far ranges. Their only armament is light, direct-fire weapons. The RED ambush is timed to ensure that all of the BLUE patrol is completely within the defined kill zone.



Source: RAND analysis.

Figure 3.7—Small Unit Infantry Patrol: RED Ambush Positions and Initial BLUE Patrol Positions

The BLUE force, also shown in Figure 3.7, is moving in four columns with a staggered 5-meter interval between troops.

Situation Assessment

The success of the BLUE force hinges on its ability to survive the ambush by returning fire while extracting itself on foot from the ambush kill zone. RED's mission is to defeat the BLUE patrol in detail by inflicting maximum attrition. RED attrition is not a principal MOE for the BLUE force.

Table 3.2 shows the base case attrition results from 30 runs of the JANUS model. No member of the BLUE patrol survives. In conjunction with the results from the Escort of a Humanitarian Convoy vignette in Section 2, these initial results suggest that any indigenous forces can inflict losses on U. S. forces that would be unacceptable to the public. The need for close support is quite evident.

Table 3.2

Small Unit Infantry Patrol: Base Case Results

Systems	Start	End	Percent Survived	Percent Total Force Surviving
BLUE				
Rifleman	25	0	0	
Javelin gunner	5	0	0	
Grenadier	5	0	0	0
Machine gunner	5	0	0	
RED				
Rifleman	33	23.3	71	
Machine gunner	12	9.3	78	72

Source: RAND analysis

Figure 3.8 is a graphic of the performance of the small unit infantry patrol when ambushed in an urban environment. The base case force, depicted as the filled-in square, represents an average survivability of zero over the course of 30 runs. About 12 RED members of the ambush team are killed by the BLUE patrol in these circumstances.

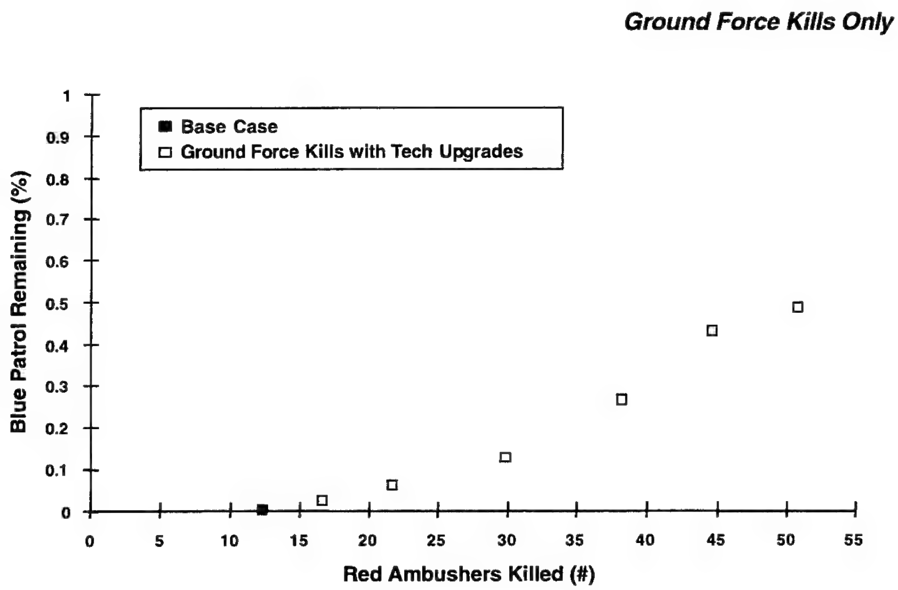


Figure 3.8—Small Unit Infantry Patrol: Force Performance When Ground Force Capability Is Enhanced

In an attempt to achieve a more desirable outcome, the engagement capability of the BLUE escorts was enhanced. In Figure 3.8, the upgraded force closest to the base case in capabilities had systems with the capability to engage targets in 87.5 percent of the engagement time needed by the systems used by the base case force. The next points represent upgraded forces that took only 75, 50, 25, and 12.5 percent of the time it took for the base case force systems to engage a new target. The systems in the most capable of the upgraded forces (the point farthest to the right on the chart) are able to engage a new target in essentially zero time. It should be noted that dramatic improvement in the lethality of the base force does very little in terms of meeting the survivability success criterion, and 50 percent of the patrol is killed in the ambush.

To further assess the patrol's survivability in this scenario, the same notional close support parametric analysis used in the study's previous scenario assessments was undertaken. This analysis was carried out by removing the *most valuable* RED forces from the vignette in order of priority before the battle was joined. The notional close support shown in Figure 3.9 removed first two, then four, six, eight, 10, 12, and 14 buildings in the order in which they fire on the patrol.

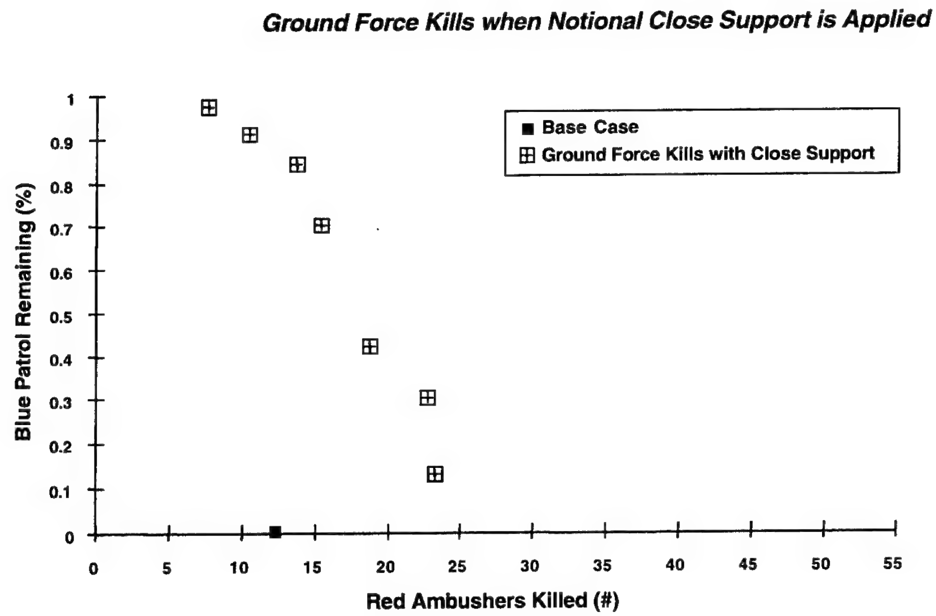


Figure 3.9—Small Unit Infantry Patrol: Ground Force Performance When Notional Close Support Is Applied

As in some of the previous vignettes we analyzed, the employment of close support dramatically improves the patrol's survivability. Because we are eliminating buildings and ambush team members in them, the number of targets available to the patrol is decreased as buildings are removed, so fewer members of the ambush team are killed by the patrol.

Figure 3.10 shows the number of RED ambush team members killed by the combined capabilities of the notional close support and the patrol itself. The removal of 12 or 14 buildings provides a reasonable level of survivability for the patrol.

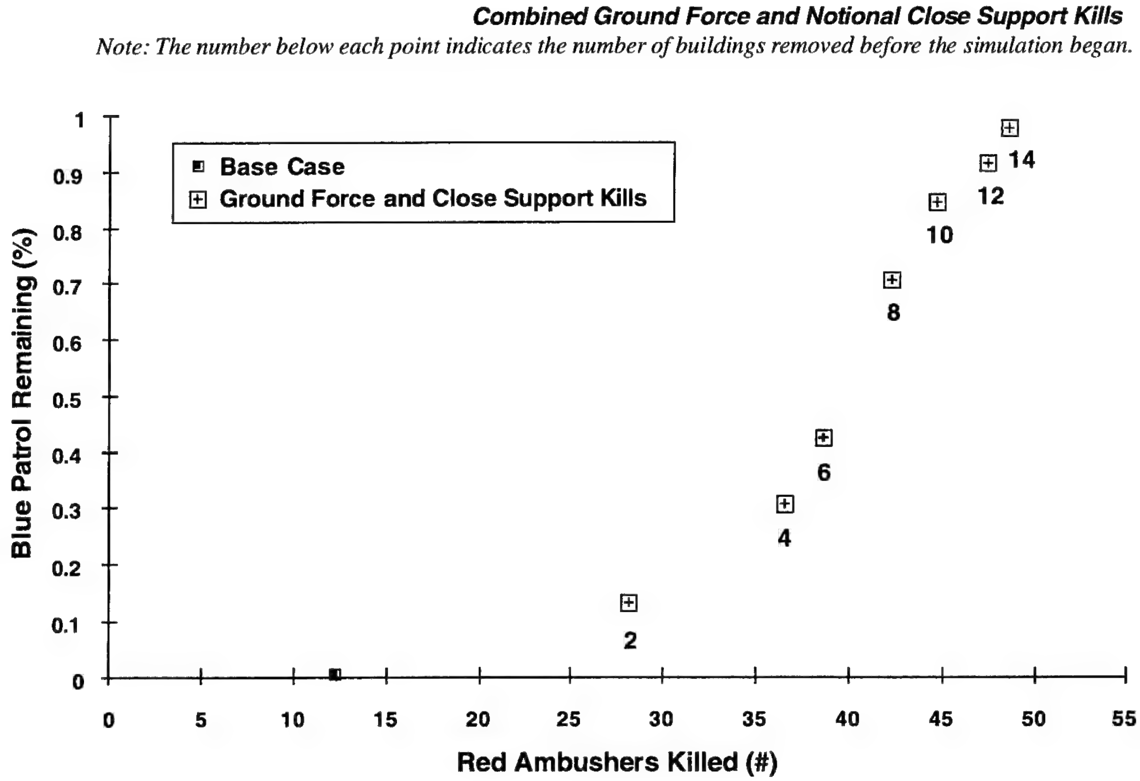


Figure 3.10—Small Unit Infantry Patrol: Combined Close Support and Ground Force Effects on the Battle

Observations on Future Close Support Needs and Desirable System Characteristics

In contrast to the previous vignettes we have examined, it is not a simple matter to provide the notional close support level of effectiveness with actual systems. Since the whole engagement is over in 10 minutes, fixed-wing systems would have to be on a local combat air patrol (CAP) in order to arrive in time to make a difference. Once they arrive, fixed-wing systems are unlikely to kill any members of the ambush team, except at the cost of significant collateral damage. Target-acquisition problems and restricted airspace make the fixed-wing option unattractive, even if targets are illuminated by the patrol.

Advanced artillery systems are equally unattractive in providing support to the ambushed patrol. Detailed fire-support plans and complex communications would be required, and then the lethality of the high-angle rounds coming down among 10-story buildings is in question. Collateral damage would be much higher than is acceptable.

Attack helicopters were employed in JANUS in an attempt to provide the needed close support. They were flown at standoff ranges to avoid small arms and shoulder-fired air defense weapons fired from within the urban environment. This was a very restrictive environment for helicopter operations. The 10-story buildings and crowded airspace made for very limited lines of sight.

Helicopters acquired an average of slightly less than one target during the missions and never fired.

Our analysis results in three observations:

Don't get ambushed. We don't see a "technology or firepower fix" for the ambush once it has begun. This statement was true for the Escort of a Humanitarian Convoy vignette and is even more imperative for the light infantry patrol in an urban environment. Providing enhanced lethality for the patrol has been shown to be of limited value. Notional close support kills more members of the ambush team but only limits the losses, and it is hard to provide using the systems under consideration. This is the most stressful vignette we studied. It is easy for the RED forces to employ and hard for the BLUE forces to counter, and it creates large numbers of casualties. These facts dramatically emphasize the importance of avoiding the ambush and hence the importance of battlefield information. HUMINT could be quite beneficial in ambush avoidance. Remote sensing could also contribute valuable information. Shoulder-held weapons such as rifles and anti-tank rockets are in effect a dipole. If remote sensors could detect these, it would provide critical warning of an impending ambush.

Responsiveness is a key requirement for close support. The short duration of the urban ambush makes responsiveness a primary requirement for close support. We believe only attack helicopter assets flying "CAP" for the patrol could currently provide a sufficiently timely response. This begs the question of providing attack helicopter support for every platoon-size patrol and assumes that there are solutions to the target acquisition problems. In the 30 replications of the JANUS simulation, over 1500 potential detection opportunities of the members of the ambush team existed. The helicopters detected targets only twice, and in neither case were they able to fire weapons. The application of advanced artillery support would require an extensive and detailed fire-coordination plan, real-time communications, and timely movement of the fire units, and it would probably generate unacceptable collateral damage.

Discriminative retribution may have deterrent value. If avoiding the ambush is not possible, the threat of retribution may deter individuals from taking part in future ambushes. As discussed previously, some form of marking, designating, or tagging the individuals involved in the ambush might be useful so that they could be punished subsequent to the actual ambush. Research into sensing, target discrimination, and marking may prove to be quite necessary.

The U.S. can not conduct peacekeeping/peacemaking missions or conduct operations other than war without the ability to conduct routine urban patrols. The ambush tactic provides what could be a dominant strategic advantage, if information warfare can not turn the tide.

Issues and Desirable Characteristics Based on These Combat Vignettes

Attack-Helicopter Issues: What Helicopter Characteristics Are Most Useful in Making the Attrition/Effectiveness Tradeoff?

As shown in both the small unit assault and the urban ambush vignettes, the ability to self-acquire targets is extremely important. A key tradeoff exists between two concepts of operations. If the attack helicopter carries only internal stores, then it retains a low-observable signature. As a result, more helicopters must be assigned to a mission to provide the total number of weapons required. The more lethal bunker- and building-buster munitions would allow the helicopters to make fewer passes in crowded airspace and hence would allow them to spend less time in the air defense envelopes.

How Can Helicopters Engage and Operate More Effectively Within the Attrition Management Window?

As indicated above, the attack helicopter usually relies on long-range target detection and acquisition capability plus high-rate-of-fire, lethal, standoff munitions to support the BLUE forces and still manage attrition. In armored combat, fire-and-forget, anti-armor systems such as Longbow provide this capability. However, such an approach is not effective in the urban ambush, because the targets in this situation can not be engaged or even detected with current sensors. The urban environment constrains lines of sight, and windows offer small apertures for observation. Additionally, there is an extreme need for responding quickly because the ambush team must be countered before it can get off a significant number of rounds.

These conditions combine to argue that the most effective strategy for countering this situation is to use sensors that can detect the location of the ambush team before the event so the ambush can be avoided. This means that instead of seeking ways to allow helicopters to engage the enemy during the ambush, the focus should be on ways to detect the ambush team and how to handle that force once it is located and the ambush avoided. Helicopters have desirable characteristics that may importantly aid this strategy, such as elevated observation positions, the ability to hover, and a speed regime that is compatible with the supported unit.

Does a Requirement to Penetrate to the Battle Location Influence the Attrition Effectiveness Tradeoff?

The ability to carry internal stores reduces the helicopter's signature as well as its drag. These two characteristics are each important when an attack helicopter has to penetrate a long distance into hostile air defenses to support a special assault. Since all of the urban environment can house a potentially hostile shoulder-held air defense system, reduced IR signature and increased

loiter capability are essential. In the cases we examined, we could not establish a need for very low radar signatures.

What Munitions and Sensor Characteristics Best Match Rotary-Wing Engagement Profiles?

In the Escort of a Humanitarian Convoy and the Small Unit Infantry Patrol, the attack helicopter is the system most likely to solve the close support challenges inherent in these vignettes. The available munitions seem more than adequate for the job. The problem is one of target location and detection. Improved sensor technology is needed to address the limited ability of close support systems to cope with an urban ambush environment. The ambush tactic provides what could be a dominant strategic advantage, if sensor technology can not turn the tide. The ability of the U.S. to intervene successfully in peacekeeping and peacemaking situations may rest on this technology improvement.

Advanced-Artillery Issues: What Are the Characteristics of an Effective Close Support Artillery System?

The Small Unit Infantry Assault mission has shown that a need exists for a small, light, 60-mm mortar that, together with enough ammunition, can be man-carried into battle over a considerable distance in bad terrain. The weapon could be designed to function for a limited number of rounds and then be discarded or destroyed before the assault force begins its withdrawal. The NLOS/FOG-M round will require enough lethality to allow it to destroy hardened bunker facilities and large, lightly constructed buildings using only a reasonable quantity of ammunition

What Effect Can Small, Deployable Packages of Advanced Artillery Have on Battle Outcomes?

The NLOS/FOG-M results from the Small Unit Infantry Assault show that the 60-mm mortar round is a contributing element to a mix of fixed-wing and attack-helicopter based close support. Furthermore, it had the psychological advantage of being entirely under the control of the assault force and hence immediately available to help cope with unforeseen circumstances. If the military complex in the vignette were also protected by ground-level, hardened, reinforced concrete bunkers, a round designed to cope with such a target would probably be desirable.

What Alternative Missions Are Required of Artillery?

The Small Unit Infantry Assault mission demonstrated the requirement to kill point targets such as weapons towers using mortar-launched NLOS/FOG-M rounds. Although not simulated, hardened, steel-reinforced concrete bunkers could conceivably have been constructed on the ground to house automatic weapons either alone or in conjunction with weapons towers. If that

were the case, then some mortar round with more destructive potential than the 60-mm NLOS/FOG-M would have been needed.

Sensors, Cueing, and Fire Control Issues: What Is the Value of the NLOS/FOG-M Target Observation (Sensing) Profile to Close Support?

In the Small Unit Infantry Assault, the accuracy of the sensing/guidance is essential to accomplishing the mission. Point targets need to be destroyed quickly by a few rounds that can be man-carried into the engagement. The accuracy also reduces the size of the warhead that is required to achieve the needed lethality and the number of rounds that need to be fired. For further discussion of this issue, see Section 5.

4. Handling "Leading Edge" Problems

A *leading edge* problem is a battlefield situation associated with the early stages of the buildup of U.S. forces in a contingency. These may be the most familiar of the combat situations in that they have many of the characteristics of the combat envisioned during the Cold War: U.S. forces are outnumbered, on the defense, and may be facing an adversary with substantial armored forces. Some aspects have changed, however, in that the emphasis in the current environment appears to be first on managing attrition and then on finding a way to conduct effective operations. Close support may play a key role in both of these objectives.

We have selected two vignettes as representative of these battle situations:

- Hasty Defense by Light Forces
- Prepared Defense by Light Forces.

Hasty Defense by Light Forces

Typical of the need for close support is the hasty defense situation involving airborne, airmobile, or marine leading edge forces. Their lightness and mobility[1] simultaneously dictates their use as the initial forces to be put in place for many operations and establishes their need for supporting firepower. This type of battle situation also has many of the characteristics of other critical battle situations, such as withdrawal.[2] Hasty defense battle situations could be characterized as consisting of two phases. In the first phase, the attacking force is largely beyond the range of the defending units' weapons and sensors (which can be as simple as tripwires and flares if the attacker is light infantry). During this phase, close support is the only practical contact the defender may have with the enemy. In the second phase, when the attacker is in the heart of the defender's weapons envelope, most of the battle is carried out with direct fire. Depending on the success of the attacker, his force composition (armor or infantry), and the range of the defender's weapons, close support may not be practical during the second phase due to the intermingling of forces using short-range weapons.[3] The first phase may be missing in some battles, as the

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[1] The mobility reference here is to inter-theater mobility. The lack of vehicles that underwrites the inter-theater mobility of the airborne forces contributes to their lack of intra-theater (battlefield) mobility and restricts their ability to use maneuver as a means of coping with mechanized forces.

[2] The withdrawal of the 2nd and 25th Infantry Divisions from North Korea after the entry of Communist China into the war poses telling examples of the battle situations associated with withdrawal and their similarity to canonical hasty defense battles (Marshall, 1953).

[3] This is not to say that the defender would not call for close support. The history of combat is filled with examples of a defender calling for supporting fire on his own position, often with the desired effect (see, for example, Moore, 1992, p. 127). The point is that defining close support system characteristics in view of this task may impose unrealistic requirements on the system.

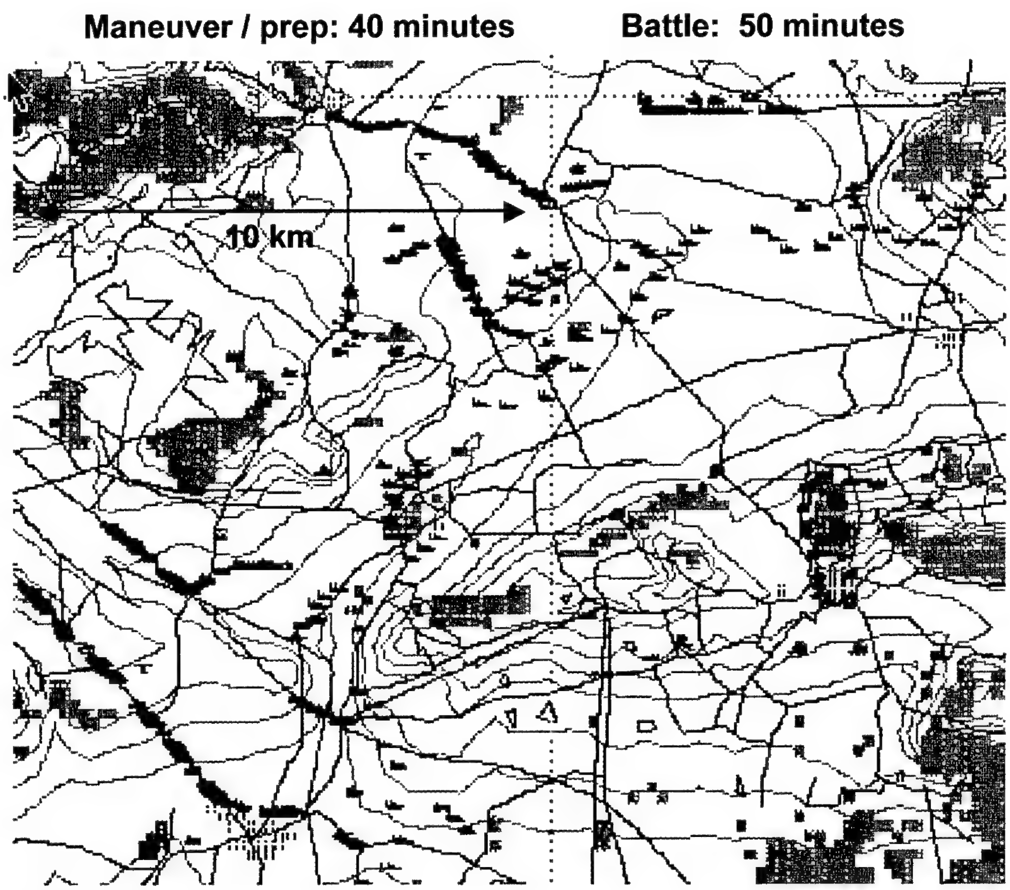
defending unit may have to fight its way into its hasty defense positions. This may preclude it from surveying the far battlefield and employing sensors (or even setting up such rudimentary sensing systems as tripwires). In the absence of a surveillance capability, it may be possible for the attacker to close on the defender's positions without being detected and engaged by close support. This is particularly true when the topography calls for the use of infantry by the attacker.

JANUS Vignette—Hasty Defense by Light Forces

We have developed a prototypical combat situation for JANUS that is representative of the hasty defense and have chosen the light force contingency in the Americas as the setting for this vignette (see Figure 4.1). The terrain is mixed, including heavily foliated steep hills and open plains. There is an extensive road network, though most are unimproved or class B roads.

BLUE forces consist of elements of an airborne brigade (roughly two battalions of light infantry—about 40 vehicle-mounted anti-tank missile launchers and fewer than 10 light armored vehicles). The BLUE force is equipped with the TOW IIB and augmented according to the current modernization plan, which adds the Javelin and the Armored Gun System (AGS) as upgrades.[4] The attacking force is an armor-heavy formation of two regiments (roughly four tank and four motorized battalions—about 275 armored vehicles) conducting a hasty attack out of a march-to-contact formation.

[4] This assumption has proven to be roughly representative of modernization plan implementation—the Javelin has since been fielded but the AGS has been cancelled.



Source: RAND analysis.

Figure 4.1—Hasty Defense by Light Forces: Initial Force Deployments

This vignette is composed of the remnants of a BLUE airborne brigade—the U.S. 82nd Airborne Division Ready Brigade (DRB)—poised to defend a critical road network capable of supporting combat air operations and other actions associated with the expansion of a lodgment. The DRB conducted a forced entry to seize a town defended by indigenous militia and reconsolidated in the town and high ground adjacent to the critical road. The remnants of the DRB must hold the town until heavy forces from the port city (lodgment) affect a linkup. The RED force consists of three regiments (the third regiment moves to the northeast to establish a blocking position and prevent the linkup by heavy forces from the port).

The terrain on which the vignette is set is mixed: flat and open with long lines of sight to the north, hilly and moderately foliated to the west, and flat and moderately foliated with shorter and broken lines of sight to the south. The weather is good, and the vignette base case involves current force capabilities for RED.

Situation Assessment

The success of the BLUE force hinges on its ability to destroy the RED force at range while retaining 60 percent of its force in order to retain the critical mass necessary to keep from being

overrun and to retain control of the town and the highway strip it commands. It is expected that if BLUE can destroy one-quarter of the RED force, it can repulse the current attack and thus allow time for reinforcements. RED's mission is to seize control of the highway strip by defeating BLUE in detail. The RED force's criterion for success is to allow no more than 25 percent of the BLUE force to survive the engagement.

After fighting through moderate opposition during the forced insertion, the BLUE force has taken up positions in a town and in key higher terrain overlooking a strip of highway to the south that is to be used as a resupply airfield for subsequent operations. BLUE's mission is to command the highway strip by fires to preclude RED forces from destroying the landing surface until heavy forces moving overland from a seaport can secure it for air resupply operations. The RED attack plan calls for a main attack to be conducted by one regiment from the west and south, preceded by a regimental supporting attack from the north and west.

The base case results, shown in Table 4.1, reflect a BLUE force with virtually no remaining anti-armor capability. Although the RED force has suffered significant casualties, it controls the road junction.

Table 4.1

Hasty Defense by Light Forces: Base Case Results

Systems	Start	End	Percent Survived	Percent Total Force Surviving
BLUE				
HMMWV-TOW	38	1	3	
AGS	8	0	0	4
Apache	6	1	17	
RED				
T-72	131	21	16	
BMP-2	132	15	11	13
BTR-60	12	0	0	

Source: RAND analysis.

With only minimal close support, the vignette runs roughly 70 minutes, during which time BLUE is defeated, though at a substantial cost to RED. Due to the mixed nature of the terrain and the hasty nature of the defensive positions that BLUE has been able to choose and prepare, the battle is characterized by short engagement ranges (inside 2 km), particularly after the initial assault by RED. Because of the compact nature of the BLUE formation, RED artillery plays an important role in the battle, accounting for at least 20 percent of the BLUE losses.

The graphical portrayal of the base case force results, depicted as the filled-in square in Figure 4.2, shows a survivability of less than 10 percent. In an attempt to achieve a more desirable outcome, the engagement capability of the BLUE force was upgraded. The upgraded force closest to the base case in capabilities had systems with the capability to engage targets in 87.5

percent of the engagement time needed by the systems used by the base case force. The point that corresponds to this upgraded force is the point closest to the base case in the figure. The next points in the sequence represent upgraded forces that required only 75, 50, and 25 percent of the time needed by the systems in the base case force to engage a new target. The systems in the most capable of the upgraded forces (represented by the point farthest to the right on the chart) are able to engage a new target instantaneously and have a single shot probability of kill (SSPK) of 1.0.

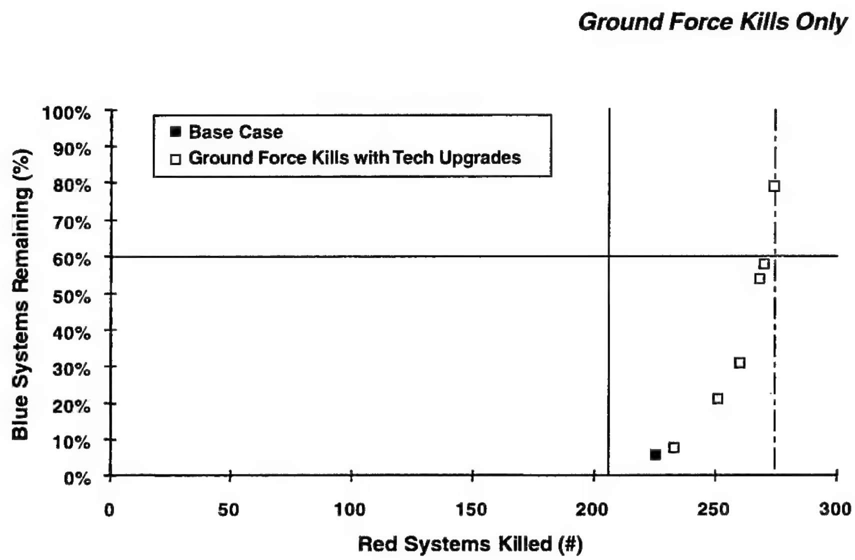


Figure 4.2—Hasty Defense by Light Forces: Force Performance with General Ground Force Upgrades

In an attempt to better understand this scenario, notional close support was provided to the forces in hasty defense. The analysis was carried out by parametrically removing the *most valuable* RED forces from the vignette in order of priority before the battle was joined. As shown in Figure 4.3, the point closest to the base case represents the case where one battalion, 30 armored fighting vehicles (AFVs), has been removed from the main RED attack. The next three points up and to the left on the graph represent two, three, and four battalions removed from the RED force before the battle begins.

As can be seen in Figure 4.3, the BLUE force survivability is enhanced, but not enough to meet the success criterion established for this vignette. The reduced number of RED forces killed by the BLUE force reflects the reduced number of targets that are available.

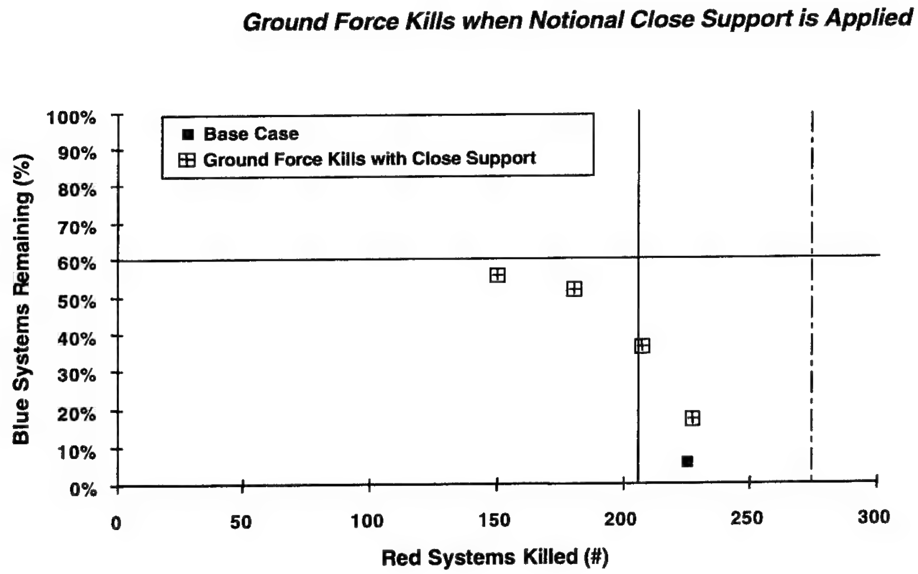


Figure 4.3—Hasty Defense by Light Forces: Ground Force Performance When Notional Close Support Is Applied

Figure 4.4 confirms the results previously shown: Over a wide range of notional close support capability, BLUE neither kills enough RED nor survives well enough to meet the "success" criterion for the vignette. However, when the study team expanded the analysis to include attacking the RED force with fixed-wing aircraft using an improved sensor-fused weapon (SFW) during its march to contact, the BLUE force was able to accomplish its mission. This is discussed in the next subsection.

Combined Ground Force and Notional Close Support Kills

Note: The number below each point indicates the number of battalions removed before the simulation began.

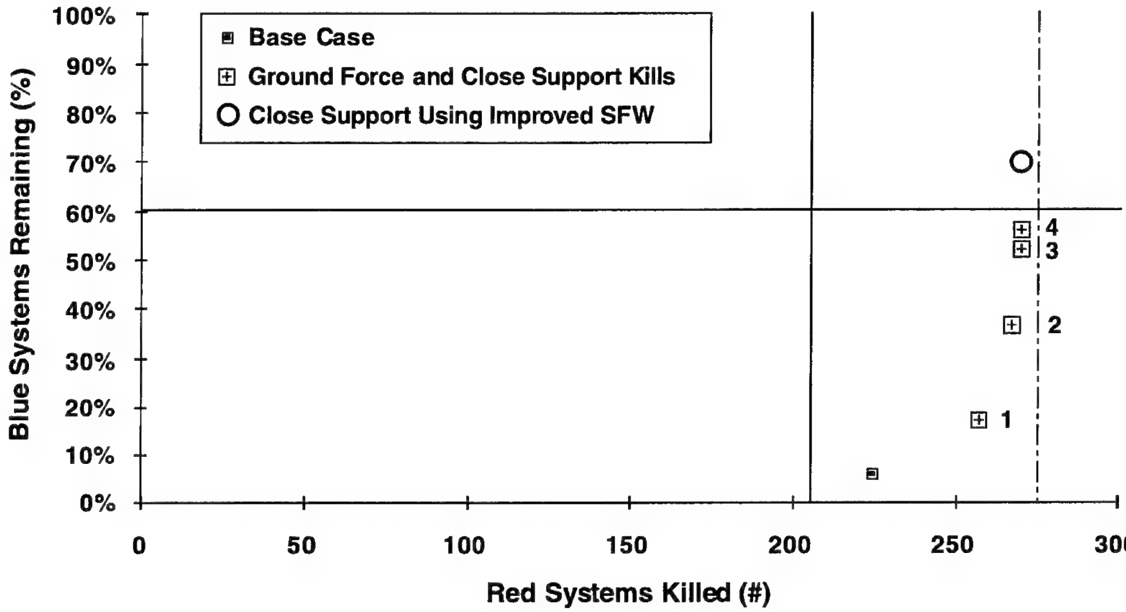


Figure 4.4—Hasty Defense by Light Forces: Combined Close Support and Ground Force Effects on the Battle

Observations on Future Close Support Needs and Desirable System Characteristics

Close support can't do it all. Two light infantry battalions require a lot of close support to hold against two heavy regiments. In the vignette we simulated in JANUS, the BLUE force is clearly overburdened; however, this is a situation that can arise, and the resulting critical battlefield situation can shed light on future close support needs.

As shown in Figure 4.4, it is possible to obtain a successful outcome in this vignette by employing fixed-wing aircraft using an improved SFW to attack the RED force during its march to contact. The improved fixed-wing munitions used for this analysis have a footprint that is 16 times the size of the current SFW footprint and a probability of kill that is 50 percent greater than that of the currently fielded SFW, but carry a payload of only five sub-munitions (in contrast to the SFW's 10 sub-munitions per dispenser).[5] This employment, however, required that the targets be attacked during their movement-to-contact phase of the battle, because even this improved munitions concept requires more time than is available in the close support phase of the vignette.

[5] For a full analysis of the effects of SFW footprint improvements, see Table 2.3.

This analysis suggests that light forces defending against massed enemy armored formations require augmentation with firepower that has the following characteristics:

- High rates of fire are needed to address several dispersed and fleeting targets quickly.
- High-volume killing capability is needed to destroy multiple-vehicle target arrays with a minimum of volleys.
- Long-range, survivable target-acquisition systems are essential to allow the close support systems to engage the RED forces well before they can engage BLUE. Because of the effectiveness of these systems, they are likely to be considered to be "high value targets" by RED and hence must be survivable.
- Information systems that allow the ground commander to coordinate the close support with his direct fire and maneuver plans are needed.
- Responsive supporting fires are needed to compensate for lack of tactical mobility. This close support must be able to slow the rate of attack or, if the BLUE ground forces need to withdraw, must keep the enemy pursuit from overrunning the BLUE forces.

Alternative approaches to the problem presented by this critical battlefield situation should be explored. Close-support-only approaches to this problem may not be practical. Our analysis indicates that at least one alternative solution—improving both the ground force and close support capabilities—may be able to handle this very demanding vignette. In our scenario assessment, the ground force improvements and close support independently were not enough to match the mission success criterion, but taken together they may provide enough capability to move the battle outcome into the success region.

Other alternative solutions should be examined as well. For example, expanding the battle space to include the movement-to-contact phase may allow the time necessary to do sufficient damage to the enemy units to improve battle outcomes. A full analysis of such interdiction approaches to the challenge illustrated by this vignette is beyond the scope of this study. We should note, however, that in the most general sense, each of the systems capable of providing close support that we are examining is also capable of providing a deeper-attack capability. Artillery is most limited in its range, although systems such as the ATACMS have significantly increased this capability in recent years. Within the area these systems can reach, current missile systems provide substantial capabilities for interdiction. Attack helicopters have both substantial range and lethality but may be limited by survivability considerations. Fixed-wing systems currently have limitations in anti-armor munitions lethality, but they have inherently greater range-payload capabilities and are more suited to the signature control that may be necessary for penetration. Given the needs of this critical battlefield situation, such dual capabilities for close support systems would appear to be a desirable characteristic.

A dual close-support/deeper-attack capability for these systems is related to a long-standing discussion concerning fixed-wing force structure design philosophy. The issue contrasts a low-cost, dedicated aircraft (with limited penetration and interdiction capabilities) with a more sophisticated aircraft capable of both missions. An overall costs-and-benefits comparison of these

two systems concepts is beyond the scope of the current analysis. But a general assessment of the advantages or disadvantages of the two platform alternatives is instructive.

To counter the survivability problems associated with penetration and deeper attack, the sophisticated aircraft rely on signature control and speed. In combination, these system characteristics decrease exposure times during penetration. These system characteristics demand sensors capable of target acquisition at extended ranges and munitions with a high lethality per pass. This provides for extended engagement ranges and fewer passes during the attack, which can limit aircraft exposure to terminal threats. Although the specifics of the system design options will differ, in general the more sophisticated systems will enhance their effectiveness potential by investing in survivability enhancements (e.g., stealth, hardness, ECM), sensors (e.g., FLIR, MMW radar), and munitions (e.g., fire-and-forget missiles dispensing smart sub-munitions) with longer range effectiveness. Speed stresses onboard sensors for target acquisition, classification, prioritization, and attack since these functions must be performed at extended range in a short time period as the aircraft closes on the targets.

A rudimentary comparison of a "light and agile" aircraft relying only on unaided visual target acquisition and low-cost weapons (e.g., cannon only) to a sophisticated aircraft sheds some light on the question of whether a dual close-support/deeper-attack capability is not only a desirable system characteristic (as indicated by our vignette analysis), but is also practical in terms of its cost or degradation to an aircraft's close support performance.

The "light and agile" class of close support aircraft would be designed to work close to the targets and defenses (e.g., small arms and light AAA, either avoiding longer-range SAMs or operating where they have been suppressed). A notional example of a plausible scaling relationship might go as follows: Suppose that a system's maximum effective standoff range for engagement (determined by its sensors and munitions) is reduced in design trades (to allow the use of less costly sensors and munitions) while its expected effectiveness per engagement is kept the same. Then the costs of the shorter-range system would have to be lower by a factor that is inversely proportional to the square of the standoff range (or even the third power under some conditions), if the shorter range design is to have the same cost-effectiveness as the longer-range design over the expected lifetimes of the two systems. This is because the apparent signature and vulnerable area that a system presents to the terminal defenses increase as its engagement range decreases, driving up its loss rate proportionally. If the exposure time per engagement increased by a factor of two due to the design choice to decrease the engagement range, then the loss rate of the less sophisticated system would be greater than that of the sophisticated system by a factor that is proportional to the cube of the decrease in engagement range.

This means that a less sophisticated design with half the standoff of a sophisticated design at its maximum engagement range would have to cost 12 to 25 percent as much as the sophisticated design to have the same cost-effectiveness (using as the measure of comparison the expected targets killed before expected aircraft loss). This, of course, means that a higher attrition rate for the less sophisticated aircraft is acceptable so long as there are no costs involved except those of

the platforms, sensors, and munitions. We will allow the analysis to use this rather unrealistic assumption for a few more paragraphs as it makes the main insights straightforward.

Design considerations that affect an aircraft's survivability can ease this challenging cost imperative. If an aircraft with a shorter standoff range also had a smaller vulnerable area (e.g., if vulnerable area were proportional to the square of the standoff range), then cost-effectiveness might be similar, depending on the sensor and munitions cost savings associated with closer operations and the likely cost increases to reduce the aircraft's vulnerability (e.g., hardening and agility).

In addition to reducing the aircraft's vulnerable area, a design could attempt to reduce the enemy's visual detection range. The potential effectiveness of signature reduction measures (of all kinds—not just visual) in close-in engagements is probably limited, but it is not as simply modeled and understood as vulnerable area improvements.

The visual detectability of an aircraft at a given range depends on several design and scenario factors. *Passive* visual detection countermeasures (e.g., paint) can help, as can design characteristics such as shape (e.g., to control glint) and size. Clearly "the smaller the better" would seem to pertain to these close support missions, but there are limits to how "small" the presented areas can be made on a manned aircraft with suitable range/payload and performance characteristics. Size scales roughly with payload. Advanced technologies can help somewhat, for example, by reducing the weight of the aircraft structure, but the fuselage will still have to be sized to accommodate the pilot and payload. *Active* visual detection countermeasures on aircraft are at least as old as World War II, when it was discovered that by turning on the landing lights during daylight attacks on German submarines the attacking U.S. aircraft could get much closer before it was detected (close enough, in fact, to sink the U-boats before they could dive) because its brightness more closely matched the bright sky background. Whether or not advanced technology parallels to the landing-lights countermeasure (e.g., smart skins that can change their color, reflectivity, and luminance to match the background sky conditions) have any utility in close support missions is unclear, but they probably have some benefit. Whether they would apply uniquely to the design concept relying on the shorter standoff range or whether such techniques would not themselves be reliant on sophisticated, high-cost systems is more doubtful.

Despite these possible complications, at its core the comparison is driven by engagement geometry and turns on this question: Can aircraft designed for close-in attacks using visual target detection and 30-mm cannons be built for a *small* fraction of the cost of more sophisticated aircraft with longer standoff and other threat avoidance/mitigation capabilities? The rational we have outlined for how small a fraction of the cost is small enough for "light and agile" aircraft to be more attractive than the sophisticated designs is certainly not definitive. But it does illustrate that it is conceivable that, if fixed-wing close support aircraft must get *closer* (to allow visual target acquisition) and fly *slower* (to allow time from target acquisition to weapons delivery), then cost reductions of an order-of-magnitude will be necessary.

While relative improvements in visual delectability and hardness may relax this cost requirement somewhat, these improvements will not provide any protection against either IR missiles and

large caliber AAA with quick reaction times encountered during the attack phase or against the longer-range SAMs encountered during penetration. These threats have larger blast warheads (in contrast to the piercing rounds used by small arms and automatic weapons), and hardening seems to provide little improvement in survivability against such threats. In the Gulf War, 40 to 50 percent of hits on "hard" aircraft by the larger warheads survived with damage while 35 to 40 percent of the "soft" aircraft survived.

Finally, even if new dedicated light and agile aircraft can be built and operated inexpensively enough to make them cost-effective relative to more capable but also more expensive aircraft, the design is predicated on higher levels of attrition and battle damage. This means additional costs (unmeasured in the rudimentary analysis above) due to higher loss of U.S. lives.[6] The resultant effects associated with higher attrition affect the national willingness to project power and public pressure to withdraw from contingencies if losses grow.

In summary, our vignette analysis has indicated that a desirable characteristic of close support systems is a dual close-support/deeper-attack capability. Advanced artillery and attack helicopters have steadily moved in this direction. However, some have argued that the speed, signature, and sensors associated with fixed-wing designs with this capability inherently weaken an aircraft's close support capability. The rudimentary analysis presented here finds no fundamental reasons for this perspective and in fact identifies reasons why such a design might also have advantages for close support capabilities as well as for deeper attacks.

Prepared Defense by Light Forces

Because of the unit strategic mobility of light forces, the beginning of a regional conflict involving U.S. forces could begin with a brigade-sized insertion of airborne or air assault forces.

Typical characteristics of such an insertion situation include

- Surprise by the inserted forces,
- A defending heavy force capable of crushing the "leading edge" force once it is alerted and if it can close with the inserted force,
- A countdown driven by the closure of the heavy forces,
- Mobility of the inserted force at the tactical unit level constrained to that of foot soldiers, and
- A need to control the battle environment with firepower (both close support and interdictive fires).

If the inserted force is able to conduct the operation according to plan, a prepared defense is possible. The use of light forces in a contingency of this type would generally be carried out within the context of an effort to gain tactical surprise. The achievement of tactical surprise

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[6]For example, it may cost millions of dollars to train each pilot. These costs alone could be large relative to the hardware costs of a new light and agile CAS aircraft.

would allow these forces to be inserted unopposed and make it possible to rapidly seize a number of natural barriers, key terrain features, and airfields. However, operations of this type would typically trigger a reaction by enemy heavy forces capable of overrunning and crushing these U.S. light infantry elements if the heavy unit can close with the inserted forces while the heavy forces are still largely intact. The time interval between the initial alerting of heavy enemy forces and their subsequent contact with the inserted force can range from hours to one or two days.

Pending the arrival of heavier U.S. forces (Marines and then mechanized Army forces), this light infantry force would initially be supported by firepower. The principle actions to be taken during this time interval would be to control the battle environment with fire to constrain the progress and number of heavy enemy forces attempting to close on the recently occupied U.S. positions.

History shows no clear examples of the use of airborne/airmobile in such a leading edge manner. We have not had the technology (strategic lift and global mobility of firepower) to effect this mission, although the use of the 82nd Airborne Division in Operation Desert Shield put that division in a situation that could have resulted in such a battle. We saw elements of this battlefield situation in Bastogne (prepared defenses for light forces, but with a strong complement of armor in the defensive force) and Arnhem (some time to prepare defenses in an urban area, but a lack of supporting firepower) during World War II.

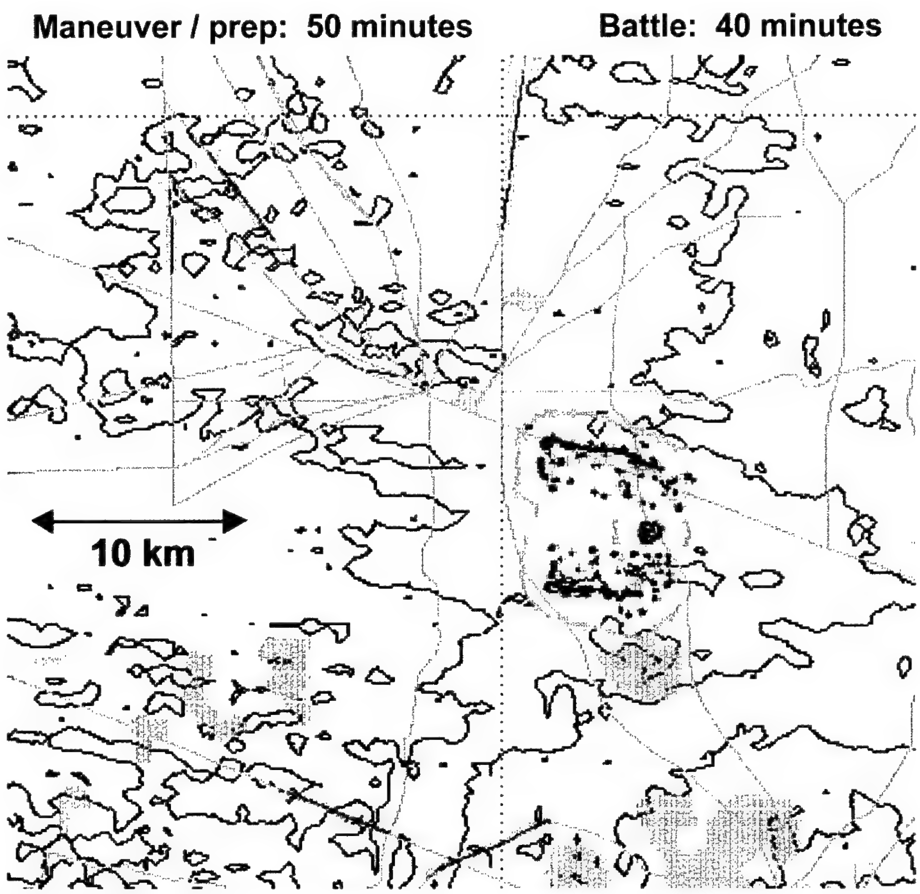
JANUS Vignette—Prepared Defense by Light Forces

We have developed a prototypical combat situation for JANUS that captures many aspects of an attack by an armored force on a light infantry brigade in prepared defenses. The vignette has been set in a locale with terrain that is favorable for armor (Southwest Asia).

As shown in Figure 4.5, the road network converges in the area; the terrain is flat, with a single rise of ground commanding the confluence of the roads.

This vignette is composed of a BLUE airborne brigade (U.S. 82nd Airborne Division Ready Brigade [DRB]) poised to defend a critical road network in northcentral Saudi Arabia (vicinity Al Wariah) against a RED force consisting of an advancing armor division of the Iraqi Republican Guard. After the insertion, BLUE has prepared positions on the higher terrain overlooking the lines of communication. BLUE's mission is to block RED forces moving south until heavy forces can provide a more substantial defense.

The DRB occupies the key terrain to the south and east of the critical road network that will become an integral part of the main supply route for the Iraqi attack targeted for Riyahd further south. The mission of the DRB is to retain control of the critical road network until relieved by heavy forces.



Source: RAND analysis.

Figure 4.5—Prepared Defense by Light Forces: Initial Force Deployments

The mission of the RED force is to defeat the BLUE airborne brigade in detail and seize control of the critical road network. To accomplish this, the RED force attacks with two tank regiments against the northern BLUE defense and one motorized regiment against the BLUE southern defenses.

BLUE forces consist of an airborne brigade (three battalions of light infantry—58 vehicle-mounted anti-tank missile launchers and 14 light armored vehicles) equipped according to the current modernization plan (the TOW IIB is augmented by the Javelin and the AGS). The RED attacking force is an armor-heavy formation of three regiments (roughly seven tank and five motorized battalions—about 511 armored vehicles) conducting a deliberate attack out of a march formation.

The terrain on which the vignette is set is flat and open with long lines of sight except in the wadis that honeycomb the area. The area is devoid of foliage. The weather is good, and the base case is defined by current force capabilities for RED.

Situation Assessment

The success of the DRB hinges on its ability to halt the RED force while retaining enough of its own forces (at least 60 percent) to retain control of the critical road network until heavy force relief arrives. It is expected that if RED losses amount to 40 percent, RED will no longer be able to continue a coherent attack. RED's mission is to clear the blocking position for follow-on formations by defeating BLUE in detail. The RED force's criterion for success is to allow no more than 25 percent of the BLUE force to survive the engagement.

The vignette runs its course in roughly 78 minutes. With minimal close support, BLUE does not have the capability to complete its mission. Due to the nature of the defensive positions that BLUE has been able to choose and prepare, the battle is characterized by high losses by RED even though RED is ultimately successful. An offensive air support plan as part of the overall operational plan would be designed to attack the road nets being used by the RED forces or interdict the RED armor as it attempts to traverse the road nets.

The base case generates the attrition shown in Table 4.2. The results are much more favorable to BLUE here than in the Hasty Defense by Light Forces, which suggests the advantage that the time for "preparation" brings to the defensive forces in the engagement.

Table 4.2

Prepared Defense by Light Forces: Base Case Results

Systems	Start	End	Percent Survived	Percent Total Force Surviving
BLUE				
HMMWV-TOW	58	27	47	
AGS	14	6	43	47
Apache	5	3	60	
RED				
T-72	311	172	28	
BMP-2	200	56	28	45

Source: RAND analysis

The aggregated base case results, shown as the filled-in square in Figure 4.6, are reasonably close to the "success" region. In an attempt to improve the outcome, the engagement capability of the BLUE escorts was enhanced.

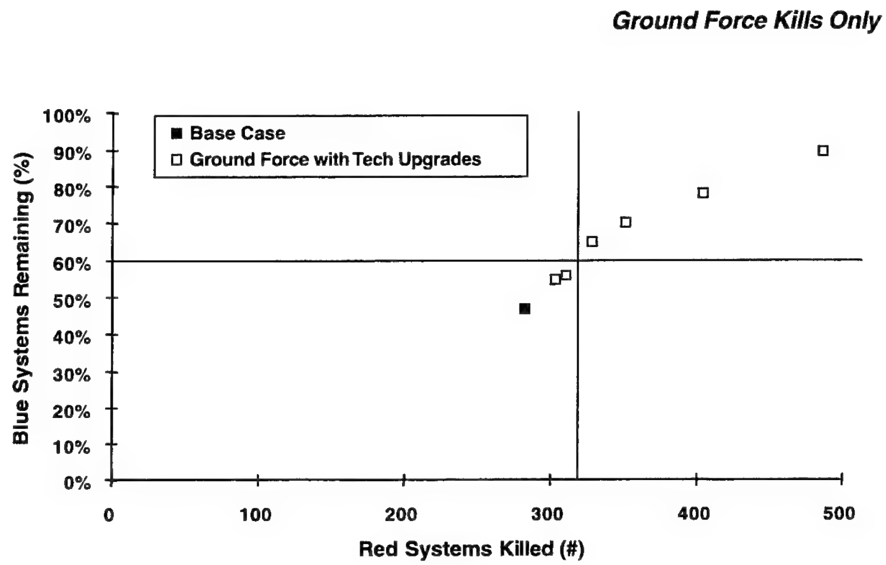


Figure 4.6—Prepared Defense by Light Forces: Force Performance When Ground Force Capability Is Enhanced

The upgraded force closest to the base case in capabilities had systems with the capability to engage targets in 87.5 percent of the engagement time needed by the systems used by the base case force. The next points represent upgraded forces that took only 75, 50, and 25 percent of the time it took for the base case force systems to engage a new target. The systems in the most capable of the upgraded forces (the point farthest to the right on the chart) are able to engage a new target in essentially zero time. Of all the vignettes we studied, this is the one in which the base force demonstrates the best performance.

Further analysis of this scenario was carried out by parametrically removing the *most valuable* RED forces from the vignette in order of priority before the battle was joined. Figure 4.7 depicts the performance of the BLUE forces when notional close support is employed to reduce the capability of the attacking RED forces. This analysis does not try to address the ability of the various methods for providing close support to achieve these results; it simply examines the scenario's response to the application of close support.

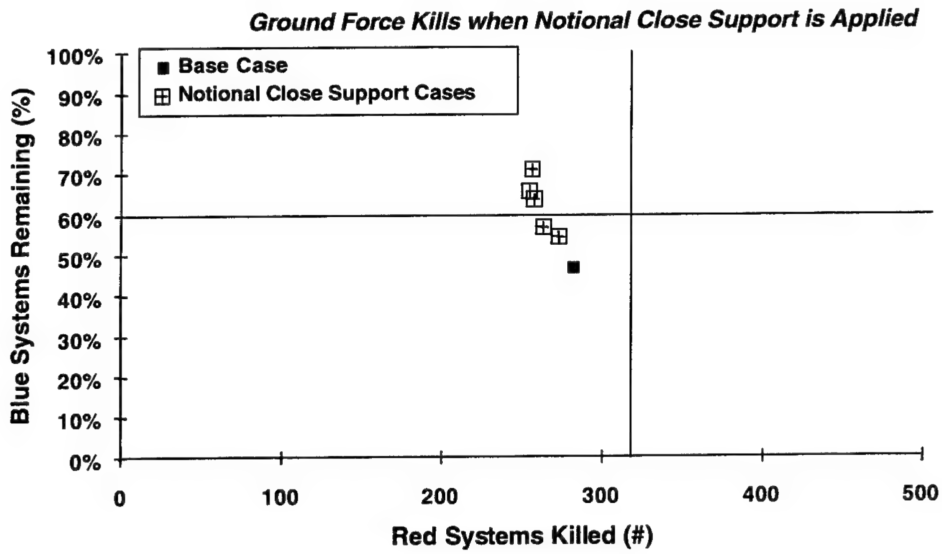


Figure 4.7—Prepared Defense by Light Forces: Ground Force Performance When Notional Close Support Is Applied

The point closest to the base case represents the case where one battalion, 30 AFVs, has been removed from the main RED attack. The next three points up and to the left on the graph represent two, three, and four battalions removed from the RED force before the battle begins.

Figure 4.8 confirms the fact that with the top two levels of close support, the BLUE forces satisfy both their lethality and their survivability goals.

Combined Ground Force and Notional Close Support Kills

Note: The number below each point indicates the number of battalions removed before the simulation began.

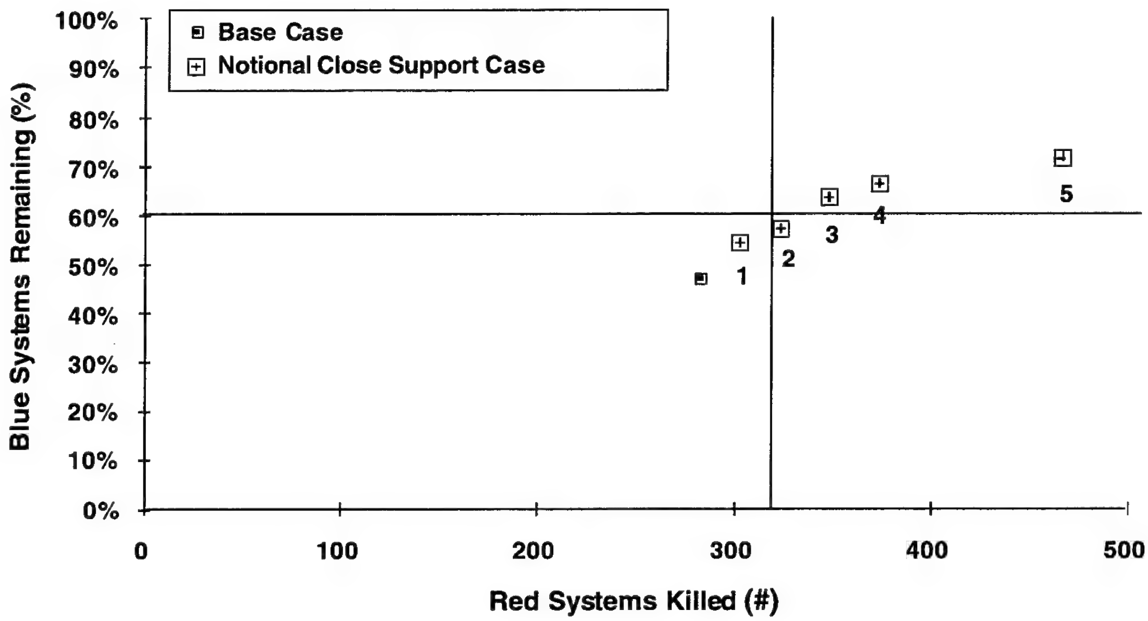


Figure 4.8—Prepared Defense by Light Forces: Combined Close Support and Ground Force Effects on the Battle

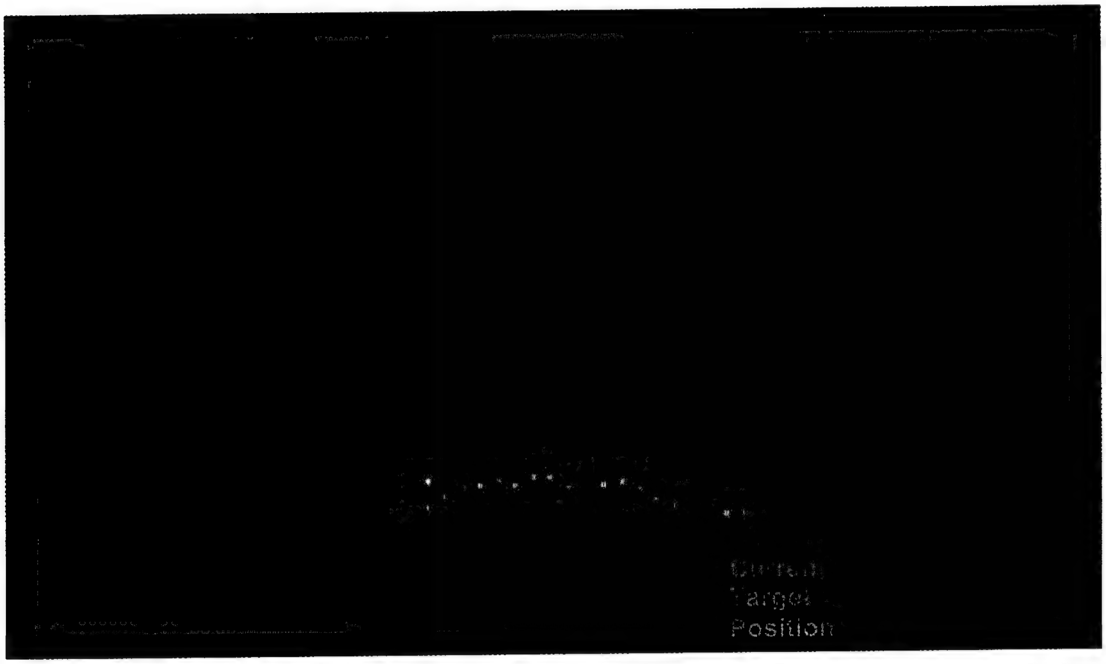
Observations on Future Close Support Needs and Desirable System Characteristics

Previous analysis and the experience of attack helicopter operations in Desert Storm imply that attack helicopters have a substantial capability against exposed armored forces. The situations in which these capabilities are most effective are when supporting friendly forces on the defense, as in this vignette, or when engaging enemy forces that can not assume an effective defensive posture due to weather or terrain, as was the case in Desert Storm. Because of this and because fixed-wing issues could best be addressed in other vignettes, the study team focused its analysis on advanced artillery in this vignette.

Effectively covering target arrays with munitions patterns. In the Prepared Defense by Light Forces vignette, we conducted a sensitivity analysis to examine how weapon footprints can most effectively accommodate the movement and different assault formations of an armored force as it transitions through the various stages of its attack. These formations include battalion columns, company columns, and company assaults (a line-abreast formation).

The effects of movement are illustrated in Figure 4.9, which shows the sensitivity of munitions effectiveness to the need to determine the appropriate lead for target movement for three munitions with different-sized footprints. As shown in the figure, the larger-footprint weapons,

including the adaptive-footprint weapons based on terminally guided sub-munitions (TGSMs), are more robust in the face of target movement.



Source: RAND analysis.

Figure 4.9—A Comparison of Munitions Footprints

The more adaptive footprint weapons (typically the concepts based on TGSMs) are also more effective when the orientation of the target is unknown or can not be compensated for by aligning the line of fire along the major axis of the target. This is often the case with all close support systems because the line between the target and the launcher determines the line of fire and it is not practical to change this in response to target orientation, even with fixed-wing deliveries.

The effectiveness of advanced artillery systems is currently most greatly constrained by their limited lethality against armored vehicles. As illustrated in Figure 4-10, DPICM sub-munitions cover a rather small area. More importantly, they match up poorly with the typical size of the targets they will have to engage on the close support battlefield (company or battalion formations).

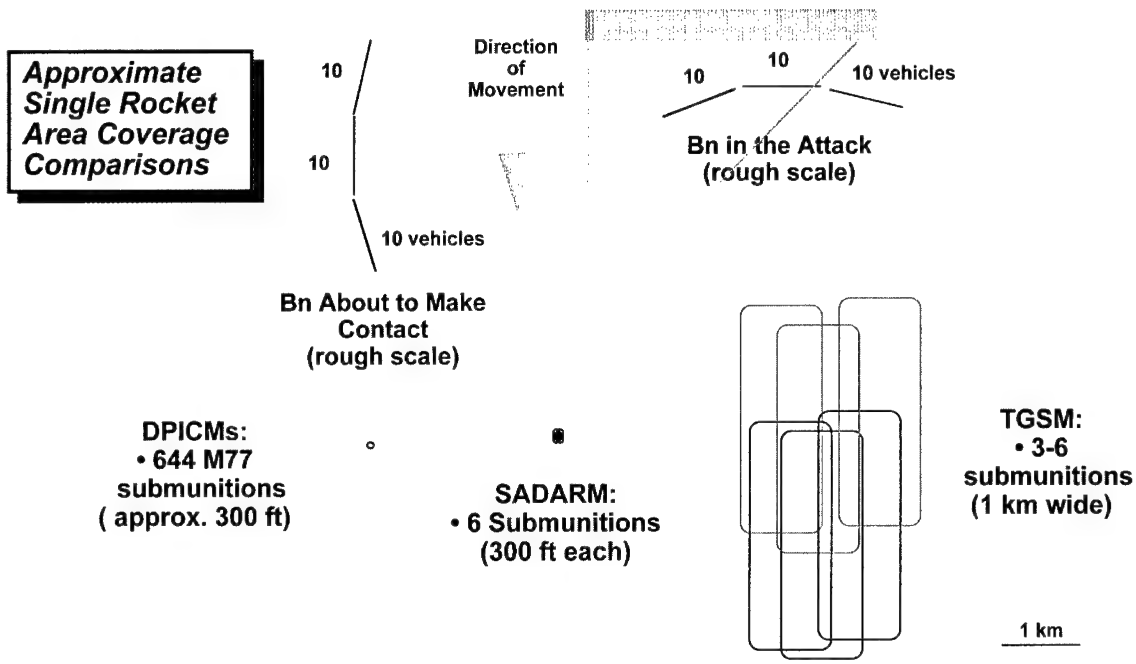


Figure 4.10—MLRS Lethality: Approximate Single Rocket Area of Coverage Comparisons to Target Size

Advanced sub-munitions such as SADARM, a sensor-fused, self-forging projectile, provide an important improvement in coverage and lethality, but effectiveness is still rather limited given target location uncertainties and weapon footprints. TGSMs, such as the IRTGSM and MMWTGSM concepts, as well as the current U.S. Army BAT concept (an acoustically cued, sensor guided sub-munition), address these target location uncertainties with dramatic increases in their lethal footprints. As a result, they promise an order-of-magnitude improvement in the ability of advanced artillery systems to influence armored combat. Previous studies suggest that the wide footprints associated with BAT (an order of magnitude greater than those with conventional TGSMs), while appropriate for road-march formations beyond the current battle may be too large for close support. This is because a firing doctrine limiting MLRS salvos to a few rockets armed with conventional TGSMs was found to best match the formations presented in the close support arena (Callero and Veit, 1993). Given these considerations, it does not appear that current advanced artillery anti-armor munitions development efforts (SADARM and BAT) will meet close support needs as well as other alternatives, such as the TGSM concepts, with roughly the same cost-effectiveness.

Informing the most effective employment of close support systems with adaptive targeting. Figure 4.11 illustrates the effectiveness of three different advanced artillery/target acquisition system options. In each case, one battery of nine MLRS launchers was deployed in support of the DRB. The three cases examined in simulation were

- MLRS-launched SADARM with perfect prebattle targeting information
- MLRS-launched Damocles with perfect prebattle targeting information
- MLRS-launched Damocles with two survivable UAVs providing adaptive targeting information

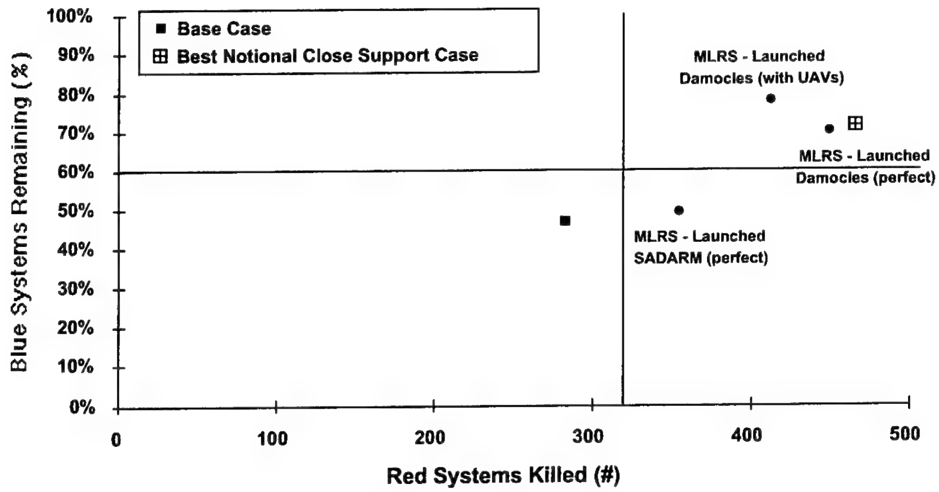


Figure 4.11—Prepared Defense by Light Forces: Adaptive Targeting of Close Support Systems

The simulation results shown in Figure 4.11 demonstrate that larger-footprint munitions (Damocles) were much more effective against moving armored formations than were smaller-footprint munitions (SADARM). In each case, an entire launcher load of 12 MLRS rockets was targeted at each company-size and larger target. For SADARM this represented 72 total sub-munitions per launcher load, and for Damocles this represented 36 total sub-munitions per launcher load. This provides further evidence that the target footprint associated with the Damocles sub-munitions was the overwhelmingly driving factor since the Damocles sub-munitions outperformed the SADARM sub-munitions despite the expenditure of only half the total number of sub-munitions.

In Figure 4.11 the "best notional close support case" is not as favorable to BLUE as the case where Damocles is launched using MLRS, targeted by a UAV orbiting over the target. This apparent anomaly is caused by the fact that in the notional close support case, RED battalions were removed from the scenario before the simulation was run and therefore without the knowledge of which RED units would be most damaging to BLUE as the battle changed over time. In the Damocles case, the UAVs were providing targeting at the company level and were positioned to adaptively choose the most dangerous RED units to target. In this situation, more of the damaging RED units were killed; hence, BLUE fared better during the simulation runs, illustrating the value of a targeting system that can adapt to the changing battle situation.

The Prepared Defense by Light Forces vignette clearly demonstrates the payoff for an adaptive targeting system complemented by an engagement system that can take advantage of such targeting. (In this case, this required an all-aspect engagement capability, sufficient range, and short lay-and-aim times.)

The value of such targeting and engagement system characteristics is shown in the improved survivability of the BLUE force achieved by the case with two UAVs providing adaptive targeting information. In the perfect prebattle targeting information cases, all launcher loads were fired early in volleys separated by 10-minute reload periods. They quickly destroyed the

targets that would have been the most damaging to BLUE if there had been no close support. This resulted from attacking the high-value formations as they first came into range, but these were not necessarily the most critical targets in the battle that developed once this close support took place. When the UAVs provided the adaptive targeting information, they metered the expenditure of rounds fired so that launchers were attacking critical targets continuously throughout the engagement.

Matching light unit strategic mobility with deployable systems. The Prepared Defense by Light Forces vignette pits a light force against a heavy armored force solely because of the former's strategic mobility. Close support systems intended to complement the light force must be equally mobile. Improving artillery anti-armor lethality through munitions improvements and targeting leads to gains that go well beyond the system's performance in the immediate tactical battle. In particular it leads to an entirely new calculus for artillery system deployability, as illustrated in Table 4.3.

Table 4.3

Deployability Improvements That Result from Enhanced Artillery Lethality

Close Support Unit		FW Squadron (18 aircraft fly)		AH Bn (15 AH / 12 OH aircraft fly)		MLRS Btry (9 launchers shoot)	
Targets to be Killed		100		100		100	
		Current Weapons	Next Generation	Current Weapons	Next Generation	Current Weapons	Next Generation
Kills per Unit During Battle		20	45	30	90	10	110
Units Needed for the Battle		5.0	2.2	3.3	1.1	10.0	0.9
Lift Sorties Needed per Unit		FTR SQDN w / maint		HHC DIV AVN BDE AH BN AVN MAINT CO		HHB DIV ARTY TGT ACQ BTRY FA BTRY MLRS	
Current fleet	C-5	1		7		2	
	C-141	22		65		57	
Future fleet	C-17	1		6		3	
	C-141	23		72		59	
Lift Sorties Required to Kill Tgts							
Current fleet	C-5	5	2	23	8	20	2
	C-141	110	49	217	72	575	52
Future fleet	C-17	5	2	20	7	30	3
	C-141	115	51	240	80	587	53
Munitions	C-141	4	2	3	1	29	3

Source: RAND analysis.

From past analyses we have seen that close support systems may be required to kill about 100 targets in a typical brigade/battalion-level battle that is characteristic of the "leading edge" situations we have identified in our scenario analysis as a critical close support situation.[7] This table details the fixed-wing, rotary-wing, and artillery forces (including munitions and support)

7Brendly et al., 1993.

needed to achieve this kill level when using both current and next-generation munitions. It compares these deployment packages in terms of the airlift requirements necessary to meet a "leading edge" requirement such as that shown at the bottom of the table.[8] The message is clear: *current* artillery is much more lift intensive (more than two times so) than helicopters, which, in turn are more lift intensive (again about two times so) than fixed-wing aircraft. But, with *advanced smart munitions*, the lift requirements for all systems are eased significantly (by a factor of two to 10) with artillery benefiting the most. The result is that with lethality advances, lift requirements become very similar to the fixed-wing lift requirements, nominating advanced artillery systems as one of the leading candidates for quick-response forces along with air power.

Issues and Desirable Characteristics Based on These Combat Vignettes

Fixed-Wing Issues:
What Fixed-Wing Speed/Signature Control Is Useful in Providing Close Support to Deeply Inserted Forces?

Our analysis of the Hasty Defense by Light Forces vignette provides a basis for identifying a deep-attack capability as a desirable characteristic for all close support systems (not just fixed-wing aircraft). An analysis of some basic factors influencing the contribution that speed, signature control, and sensors make in cost-effective accomplishment of deeper-attack missions noted that these systems capabilities also serve to enhance close support effectiveness. As a result, we find no basis to distinguish between the signature, speed, and sensor suites that would be desirable for canonical close support, close support for deeply inserted forces, and deeper-attack or interdictive missions against enemy forces. A capable attack aircraft is necessary for all of these missions.

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[8]Table 4.3 incorporates certain simplifications, which err in favor of fixed-wing aircraft and helicopters, to provide an *a fortiori* argument that advanced artillery systems are lift competitive. For example, it is unlikely that much more than one squadron of fixed-wing aircraft could be effectively employed in the airspace above a battalion-level battle during the times these engagements take place. This is due as much to factors of physical airspace size and the need to separate flights of "fast moving" fixed-wing aircraft as it is a function of the time it would take to coordinate a CAS sortie from initial check-in of the flight at the contact point (CP), to the initial point (IP), to target run-in, to, finally, egress from the area. Such a run may take as long as 10 minutes from start to finish for a section of two aircraft before the next flight of aircraft could be cleared into the target area. As a result, the fixed-wing force could not effect the level of kills described in a given battle (although it could *across the theater*).

Advanced-Artillery Issues: What Are the Characteristics (Footprints and Target Types) of Effective Close Support Systems?

The simulation results from the Prepared Defense by Light Forces vignette demonstrate that larger-footprint munitions were much more effective against moving armored formations than were smaller-footprint munitions. This is because they can most effectively accommodate the movement and different assault formations of an armored force as it transitions through the various stages of its attack.

What Effect Can Small, Deployable Packages of Advanced Artillery Have on Battle Outcomes?

It is important to point out that the "small, deployable packages of advanced artillery" differed with each vignette according to the type of forces employed. In the Small Unit Infantry Assault vignette, these systems were 60-mm mortars firing FOG-Ms, which were carried to the battlefield by the support force. The mortars made a substantial contribution to the satisfactory competition of the mission. In the two vignettes analyzed in this section, this capability was provided by one battery of nine MLRS launchers. As we have shown, the MLRS launchers were able to provide the additional capability necessary to move the results into the "success region" for the vignette.

5. Supporting Mechanized Offensive Operations

Since Vietnam, U.S. doctrine has moved to a fighting concept that calls for the engagement of enemy forces long before they come in contact with U.S. forces, thus reducing the need for close support. The technology the U.S. has already employed in combat has shown that it is practical to engage the enemy before being committed to close battle (for mechanized combat), but even when this capability has been effectively employed, a close combat phase may be required to decide the battle. Because of the high casualty potential of such operations, improvements addressing other shortfalls in close support capabilities (supporting allies, light infantry, and leading edge forces) would need to be developed in a manner that preserved (or even enhanced) the U.S. capability to *support decisive operations in mechanized battle when the U.S. enjoyed the initiative*. Although the U.S. relies on a doctrine that in the main would prefer more distant engagements, both battle experience and analysis indicate that close support will be the most effective way to shape battle outcomes at some times and places during the course of a conflict.

We have selected the Armored Force Meeting Engagement as a combat vignette typical of these situations.

Meeting Engagements

Meeting engagements take place when forces conduct offensive operations to establish or regain contact with an adversary who is likewise moving to contact. Often in a race to an objective or to occupy key terrain, forces make contact by chance while on the move. Sometimes, however, meeting engagements occur even when each opponent is aware of the other; both decide to attack without delay in an attempt to achieve a decisive advantage.

Commanders usually lead with self-contained forces that are capable of locating and fixing the enemy, holding back the bulk of their forces so that when the lead forces make contact they can maneuver the majority of their force without becoming decisively engaged until they choose to do so.

Meeting engagements usually transform themselves into two general categories of situations: When a force encounters a larger enemy or when the terrain offers an advantage, commanders may opt for a hasty defense to force the enemy to fight in the open.[1] Alternatively, commanders may elect to conduct a hasty attack before the enemy is able to concentrate its forces or to establish a defense. In either case, the more closely maneuver and supporting elements can

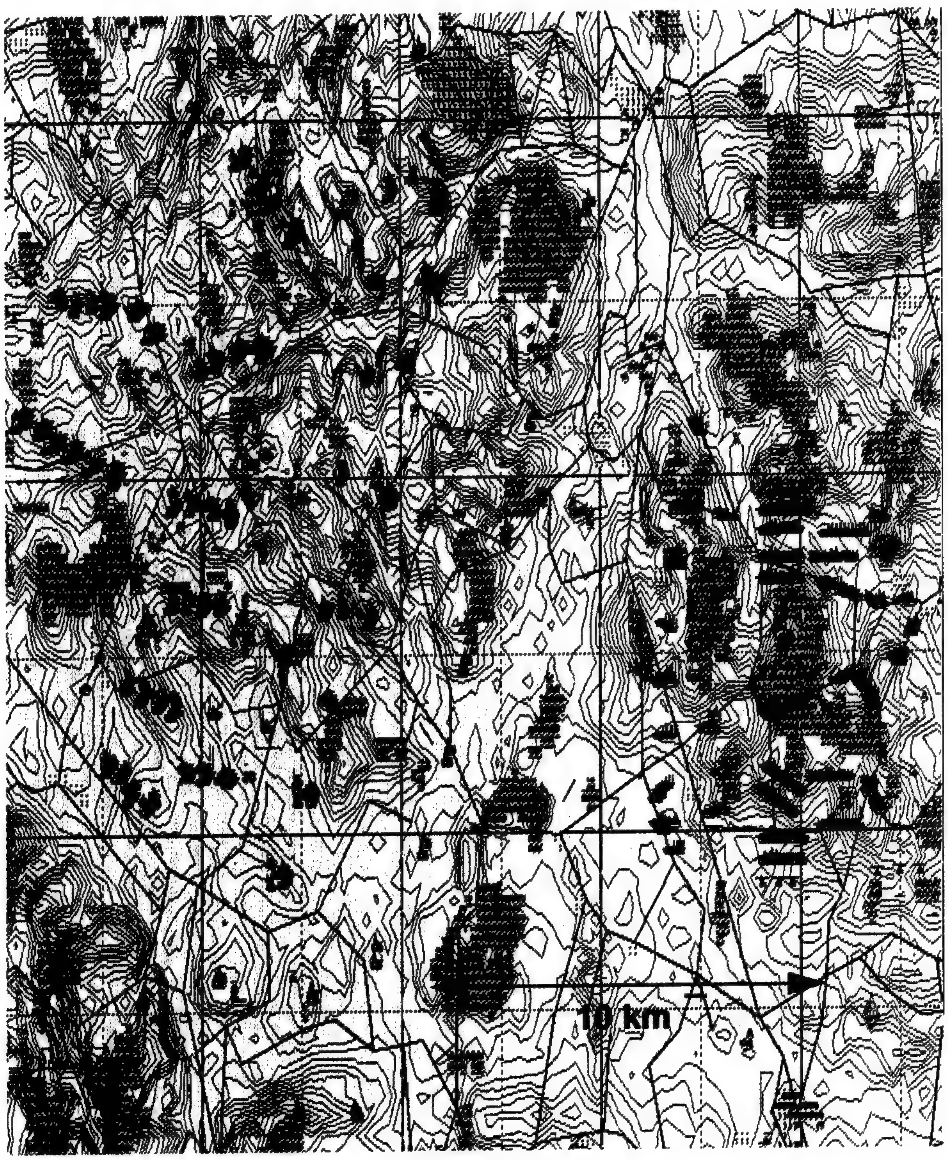
[1]The initial contact between the first companies inserted into LZ X-Ray in the Ia Drang Valley of Vietnam (Bravo Company and Alpha Company, 1st Battalion, 7th Cavalry) and the lead battalions of the two North Vietnamese regiments operating in the area (the 9th Battalion, 33rd Regiment and the 7th Battalion, 66th Regiment) provides an apt historical example of meeting engagements and how they evolve into a hasty defense situation (Moore and Galloway, 1992).

coordinate before the engagement, the more successful and effective the ensuing attack or defense will be.

Meeting engagements can be thought of as having three phases: contact, transition, and the resulting defensive or offensive engagement.

JANUS Vignette—Armored Force Meeting Engagement

For the meeting engagement, we developed a JANUS vignette sited in northcentral Europe. The battle situation is shown in Figure 5.1. The terrain is rolling with some foliage; there is an extensive road network and there are numerous small villages.



Source: RAND analysis

Figure 5.1—Armored Force Meeting Engagement: Initial Force Deployments

A BLUE leading edge force of reinforced-brigade size (four battalions plus a division cavalry troop) is moving to close on its objective as quickly as possible. This armored formation encounters a RED force of similar size (a tank regiment of four battalions). Both units engage from the march formation, BLUE undertaking a hasty attack, and Red posturing for a hasty defense. BLUE's mission is to cause RED to withdraw or defeat the incursion force in detail; RED's mission is to hold its position.

This vignette is composed of a BLUE heavy brigade led by a troop from the division cavalry moving to intercept and engage a RED force consisting of a Former Soviet Republic's (FSR's) tank-heavy mechanized regiment conducting an incursion into eastern Poland. The two forces meet head on, with the RED force seizing the advantageous terrain for a hasty defensive position on a ridge with commanding fields of observation and fire.[2] Because of the relative location of reinforcing units, BLUE must transition into a hasty attack on the RED defensive positions. If BLUE were to delay the attack to maneuver around the high ground held by RED, or attack under cover of darkness, the RED reinforcements would have joined the forward regiment, and RED would strongly outnumber the BLUE force.

The terrain on which the vignette is set is rolling hills with moderate foliage and is considered to be well suited to the conduct of armor operations. The weather is good, and the base case is defined by current force capabilities for both RED and BLUE.

Situation Assessment

The success of the assaulting force hinges on the ability of BLUE ground forces (mainly tanks) to acquire and engage the RED vehicles in defilade on commanding terrain. Thus, the success criterion for the BLUE force requires that 70 percent of the original attack force survive while destroying 75 percent or more of the RED regiment.

After the initial clash of forward elements of each of the units, the RED hasty defense posture is identified, and BLUE forms in its assault positions on high ground from 5 to 6 kilometers from the RED forward positions. The main BLUE attack is conducted to the north with a supporting feint by one battalion in the south. Infantry fighting vehicles (IFVs) attempt to engage the RED defenses from maximum standoff. Preparatory fire is provided by one battery of multiple launch rocket systems (MRLs) firing several launcher loads of dual purpose improved conventional munitions (DPICMs). Target acquisition for the supporting artillery is provided by an organic fire support team (FIST) and unmanned aerial vehicles (UAVs).

The base case results in the attrition shown in Table 5.1. These results reflect the difference between BLUE on the attack and RED in a hasty defense, a situation that is RED favorable. In addition, in this case we are seeing the difference when the less capable T-72 is engaged with the M1A1.

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[2]The terrain advantage will be apparent in the lethality of the RED air defense when engaging BLUE fixed-wing systems.

Table 5.1

Armored Force Meeting Engagement: Base Case Results

System	Start	End	Percent Survived	Percent Total Force Surviving
BLUE				
M1A1	108	28	26	
IFV/CFV	138	40	29	
ITV	24	0	0	30
Apache	6	6	100	
FIST-V	12	11	92	
RED				
T-72	120	46	38	
BMP-2	58	12	21	
BTR-60	10	5	50	34
HIND-E	6	0	0	
HAVOC	6	1	17	
SA-15/2S-6	24	13	54	

Source: RAND analysis

The filled-in square in Figure 5.2 is a graphical portrayal of the results of the baseline forces in the meeting engagement. Only 30 percent of the BLUE force survives.[3] Under the circumstances, this calls into question the tactic of accepting a frontal engagement against a dug-in armored force, rather than maneuvering around the force and causing it to come out of its dug-in positions, or waiting to attack after dark when the M1A1 fire control would dominate the engagement. However, as previously discussed, the opposing RED force will be strongly reinforced if the BLUE brigade delays its attack.

[3]The battle of 73 Easing was unusual in that the enemy armor (T-72s), while very similar in capability to those we examined in the simulation, were blind. The battle occurred just after a sandstorm and took place in the early morning hours. The Iraqi T-72s did not have thermal or infrared sensing capability and were engaged at long range, by M1A2s and M2 Bradley fighting vehicles, both equipped with thermal sights. The case here is similar; the enemy has gone to ground and is in a defensive posture, but the similarity ends there. The weather in our vignette is fair to good, and while BLUE still has a significant sensor advantage, the advantage is more than negated by the defilade posture of the defending enemy armor. Add to that the fact that BLUE is moving and the enemy is stationary. This constitutes a favorable situation for RED. This explains the difference in results between our simulated vignette and the battle of 73 Easting.

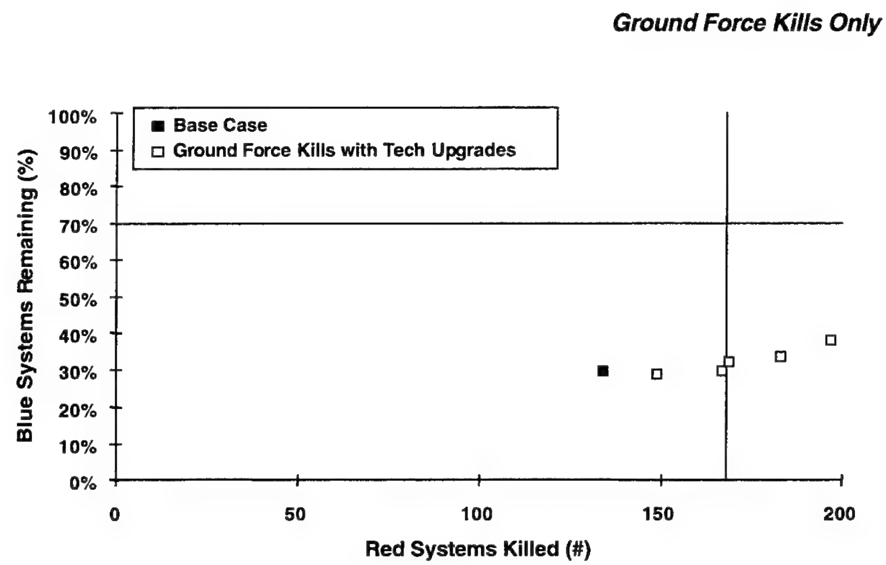

Figure 5.2—Armored Force Meeting Engagement: Force Performance When Ground Force Capability Is Enhanced

In an attempt to achieve a more desirable outcome, the engagement capability of the BLUE force was enhanced. The enhanced force nearest to the base case is able to engage targets in 87.5 percent of the time required for the base case force. The next points represent forces that require only 75, 50, and 25 percent of the time it takes the base case force to engage a new target. The forces represented in the uppermost point to the right of the chart are able to engage a new target in essentially zero time. Although substantially more RED AFVs are killed, the survivability of the BLUE forces is far below the desired outcome.

This scenario was assessed in more depth by parametrically removing the *most valuable* RED forces from the vignette in order of priority before the battle was joined. Figure 5.3 depicts the performance of the BLUE forces when notional close support is employed to reduce the capability of the RED forces. This parametric analysis does not address the ability of actual systems to provide this level of close support.

The notional close support case point coincident with the base case represents the removal of 10 AFVs from the RED forces facing the BLUE main axis of attack. The next eight points up and to the left on the graph represent 20, 30, 40, 50, 60, 70, 90, and 110 AFVs removed from the RED force before the battle begins. The BLUE ground forces kill fewer and fewer RED forces as additional notional close support is provided because they are experiencing a shortage of targets.

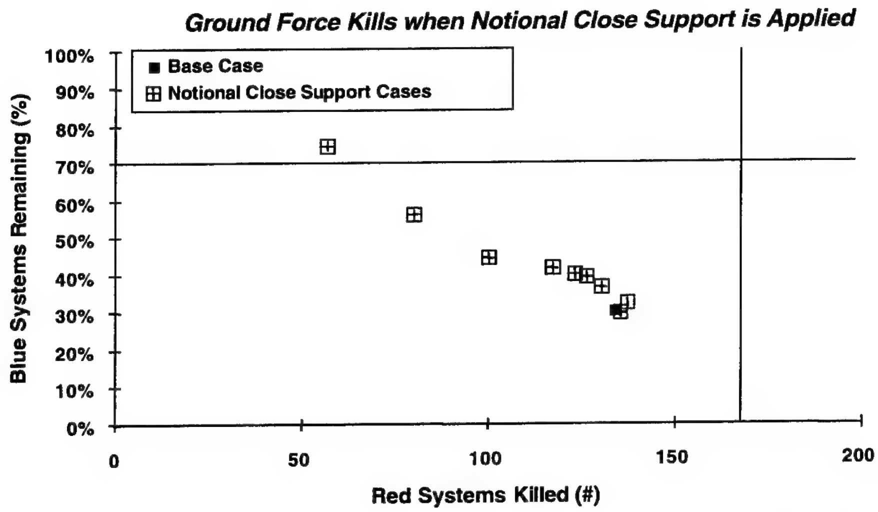

Figure 5.3—Armored Force Meeting Engagement: Ground Force Performance When Notional Close Support Is Applied

Unlike the case where the ground force performance was enhanced, the BLUE close support does substantially improve the survivability of the BLUE ground force to the point that it is in the "success region."

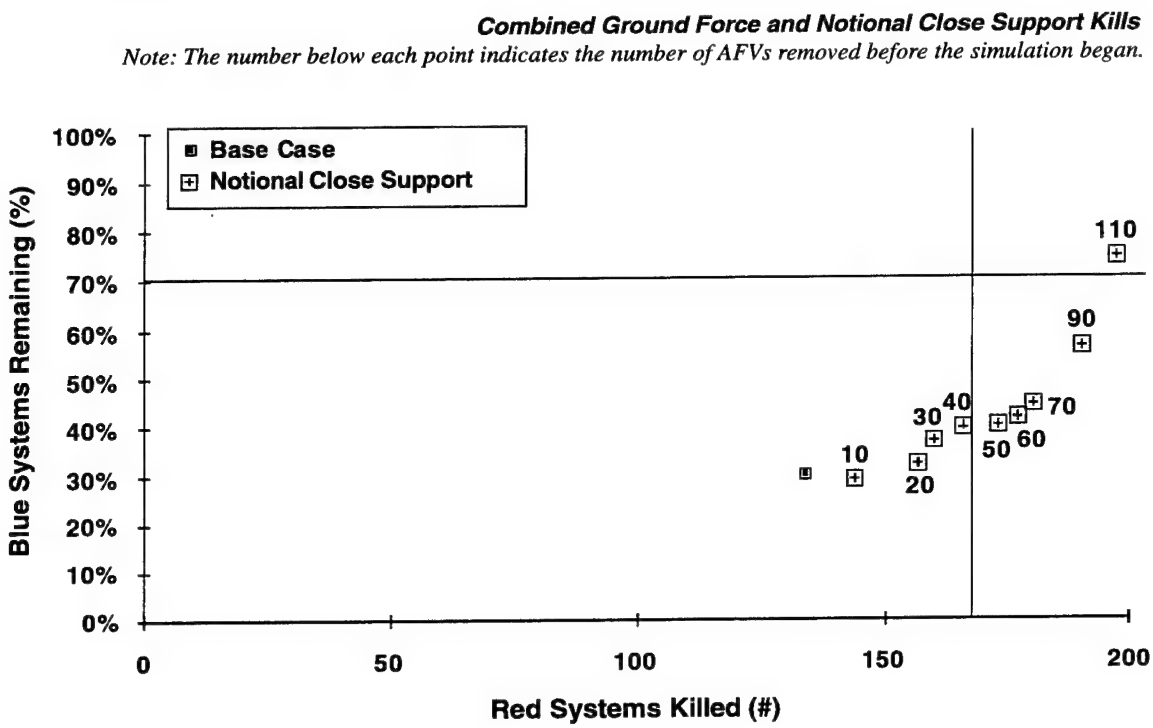

Figure 5.4—Armored Force Meeting Engagement: Combined Close Support and Ground Force Effects on the Battle

Figure 5.4 shows the combination of the RED defenders killed by close support and by the BLUE attackers. Not surprisingly, as the amount of close support increases, the BLUE force survives better and more RED forces are killed. With close support, the BLUE forces achieve the desired survivability as well as the desired RED kills.

Observations on Future Close Support Needs and Desirable System Characteristics

Notably, the Armored Force Meeting Engagement is one of the vignettes in which the actual close support systems that we employed are unable to deliver the amount of lethality provided in the "notional close support" case during the course of the battle. This outcome is largely determined by limiting the employment of these systems to the close support regime (no interdiction or battlefield interdiction missions engaged the RED force prior to its first engagement of BLUE). While this constraint is a result of the study's analytic charter, it is not inconsistent with a real-world situation in which the intentions of the RED force are unknown until shots are fired.[4]

Our analysis examined fixed-wing munitions employment, the use of advanced artillery, and adaptive targeting systems.

Fixed-Wing Employment. Figure 5.5 shows the results of 18 F-16s, each making four passes, delivering SFWs dispensed from TMDs. This shows that although four of the cases under which the SFW was delivered achieve sufficient RED kills, none of the fixed-wing systems is able to come close to the desired BLUE ground force survivability. (See Table 2.3 for a specification of the SFW employment cases.) In all cases, SFW effectiveness was limited by both the dug-in posture of the RED force and the limited ability of the aircraft to line up the long, narrow SFW footprint with a linear array of target vehicles in this tactical situation. Since weapon-pattern/target-pattern matching is one of the primary determinants of munitions effectiveness, our assessment of the SFW's overall effectiveness is lower than that usually found in studies that make less realistic assumptions about the tactical situation and employment.

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[4]NATO forces were faced with s similar situation during the initial hours of the deployment into Kosovo as a Russian unit occupied the airport.

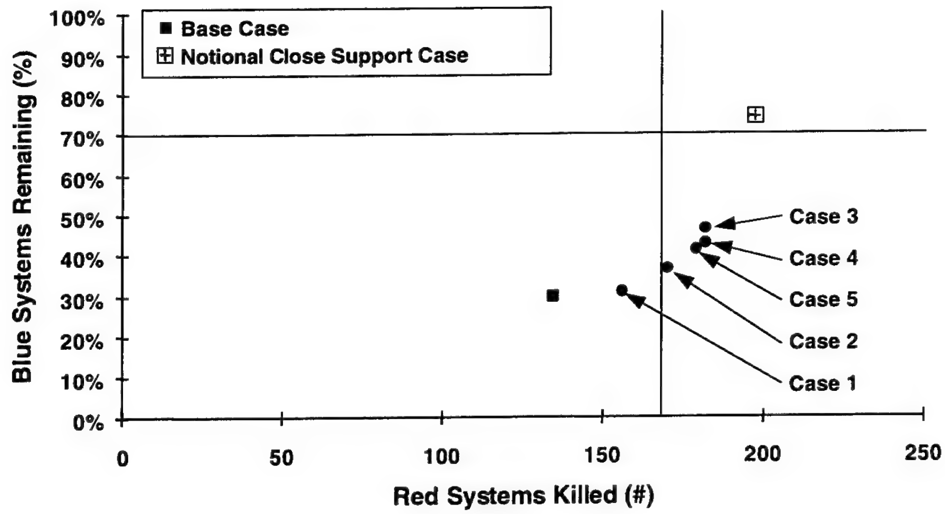

Figure 5.5—Armored Force Meeting Engagement: JANUS Results, Fixed-Wing-Delivered SFWs

The fixed-wing Maverick missile employment was also studied in the context of this vignette. A force of 18 F-16s, each carrying four Maverick missiles, engaged the RED hasty defense position. The aircraft ingressed at 400 feet and 450 knots, popped up to 1500 feet, rolled over into a 20-degree dive, and spent 10 to 12 seconds attempting to acquire and lock on to the target and launch the missile. The 18 attacks detected targets 105 times, launched eight missiles, and resulted in one tank kill. Figure 5.6 shows the distribution of these events. This relatively shallow angle of attack (20 degrees) and short time to acquire a dug-in target (10 to 12 seconds) resulted in very few detections early in the attack profile. Since the presented area of a dug-in tank is half the normal presented area, both the detection capability and the lethality of the missile were degraded.

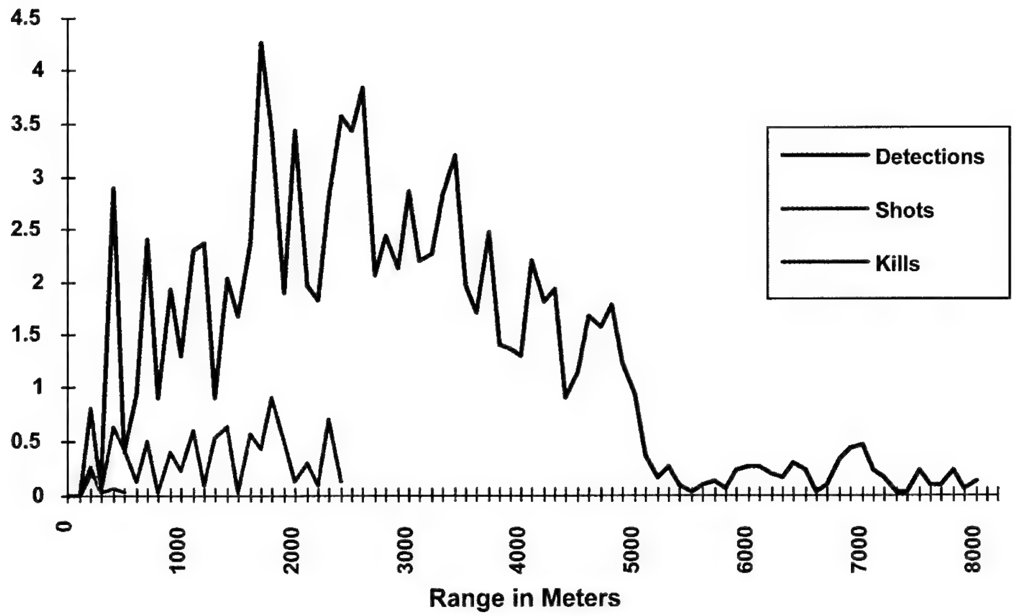

Figure 5.6 – Armored Force Meeting Engagement: JANUS Results, Fixed-Wing-Delivered Maverick Missile Engagement Profile

These results may suggest that the F-16 was employed in too conservative an attack profile. However, the RED forces are dug in on terrain that commands the surrounding area. The 24 SA-15/2S-6 air defense systems force the F-16 to employ the conservative attack described above and still kill twice as many of their targets (F-16s) as the F-16s (which target tanks) do. Although the F-16s could attack more aggressively, and re-attack the target arrays, trading two aircraft for each tank killed seems like a losing proposition. Although it appeared to exhibit some of the desirable engagement characteristics of the advanced artillery, the Maverick missile proved to be ineffective in the scenario that was simulated. It seems clear that if the Maverick missile is to make a significant contribution to the lethality and survivability of the BLUE ground force, a significant SEAD campaign will be required to suppress the RED defenses.

Advanced-Artillery Employment. Figure 5.7 shows that both the MLRS-launched Damocles and the enhanced fiber-optic-guided missile (EFOG-M) were quite effective against the stationary, dug-in target arrays. The high angle of approach of the weapons, to a large extent, negated the fact that the targets were in defilade. As we previously discussed, this amount of RED attrition was generated by a "brigade slice" of the divisional MLRS.

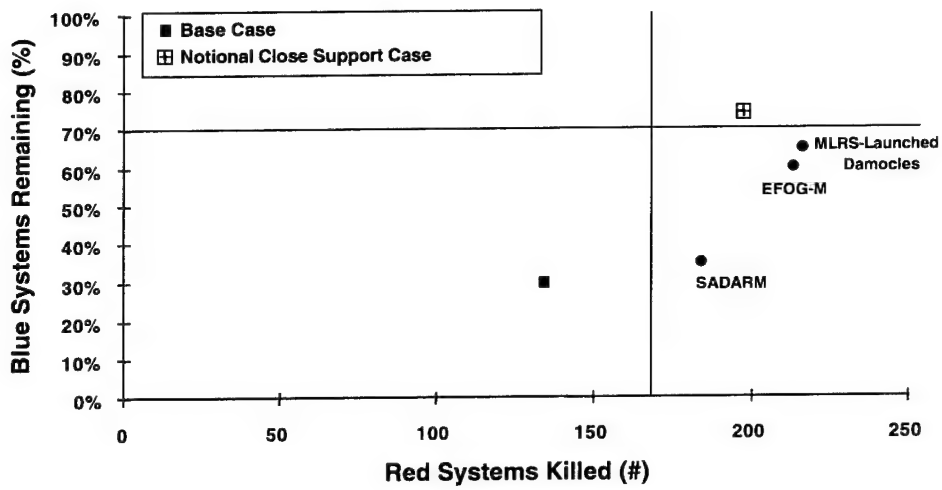

Figure 5.7—Armored Force Meeting Engagement: Advanced Artillery Employment

This performance was in contrast to the performance of the MLRS-launched SADARM. The comparatively large footprints associated with Damocles and EFOG-M virtually guaranteed the acquisition of several targets by each munition (see Figure 4.11).

Because the advanced artillery was organic to the BLUE maneuver force, that force was able to bring its munitions to bear on the RED armored formations while they were still moving and therefore easier to acquire. While this was a real plus for Damocles and EFOG-M, this had a negative impact on the performance of the SADARM munitions because it revealed the munitions' relative ineffectiveness against moving target arrays due to the relatively small munitions footprint.

A close examination of the results yielded the following insights:

Desirable characteristics for close support munitions. In the main, fixed-wing munitions could not be brought to bear on the enemy formations before they had stopped and assumed a hastily dug-in (defilade) posture. Due to the short time in which this transition takes place, it was not possible for the fixed-wing assets to engage RED targets in the open (in march- or movement-to-contact formations) where current munitions are effective. The in-defilade posture of the targets made acquisition by the munitions' sensors even more difficult than would have been expected considering their relatively small footprints, and resulted in a limited ability of the fixed-wing to destroy the RED forces in the time required.

The relatively slow descent of the Damocles sub-munitions and the slow speed of the EFOG-M, when coupled with their large footprints, maximized their opportunities for engagement. While the rate of descent/slow speed was also a characteristic of both SADARM and SFW, their restrictively small footprints limited their effectiveness.

Adaptive targeting systems complement advanced close support munitions capabilities. Our situation assessments suggest that there is an important payoff to serving the right target at the right time. The target acquisition for all of the advanced artillery cases was provided by

unmanned aerial vehicles (UAVs). The UAVs were capable of providing real-time BDA when targeting the armored formations for the firing batteries. This permitted the timely targeting of the most lucrative target arrays. By contrast, targeting for the fixed-wing delivered SFW, while perfect in geo-positioning, was accomplished far in advance of the actual arrival of the sub-munitions on the target arrays, thereby reducing overall efficiency.

Issues and Desirable Characteristics Based on These Combat Vignettes

Fixed-Wing Issues: What Level of Tactical Standoff Is Most Practical for the Current Fixed-Wing System's Attack Profiles?

The comparison between the long-range standoff employed in the "lofted" delivery tactic of the SFW and the 7-kilometer standoff for the Maverick missile illustrates that the maximum standoff at which no lethality degradation occurs is the best for the fixed-wing survivability/effectiveness balance. It also illustrates the conditions that determine which characteristics are more complex in light of the wider range of employment scenarios the U.S. now faces in the new defense environment. Against an offensively postured threat, the Maverick's engagement range might be expected to give it an edge, and improvements in its engagement rate might seem the next most effective enhancement. But in this situation, the missile was severely degraded by the extremely small presented signature and vulnerable area of the in-defilade AFVs, and there would be little payoff to such improvements.

What Munitions and Sensor Characteristics Best Match Fixed-Wing Engagement Profiles?

Due to the constraints of this scenario, fixed-wing munitions could not be brought to bear on the enemy formations before they had stopped and assumed a hastily dug-in (defilade) posture. The in-defilade posture of the targets made acquisition by the munitions' sensors even more difficult than would have been expected considering their relatively small footprints and resulted in a limited ability of the fixed-wing to destroy the RED forces in the time required. Existing munitions and sensor characteristics support the survivability requirements of fixed-wing deliveries, but to meet the success criterion of this very demanding scenario, sensor and munitions characteristics will need to support nearly twice the engagement rate of the best current systems.

Advanced-Artillery Issues:
What Munitions and Sensor Suites Best Match Artillery's Indirect Fire Method of Engagement?

The high-angle trajectory of the advanced artillery gives it an advantage over fixed-wing aircraft or attack helicopters in the meeting engagement where the RED AFVs are in defilade. The UAV-cued advanced artillery, either MLRS or EFOG-M, enjoyed the advantage of being able to engage the most lucrative of the enemy formations.

What Effect Can Small, Deployable Packages of Advanced Artillery Have on Battle Outcomes?

Deployable is a relative term. "Small, deployable" in the context of the Small Unit Infantry Assault refers to a 60-mm mortar that is carried into the fight by the Special Forces assault group. In the context of the Armored Force Meeting Engagement vignette, the MLRS is a small, deployable package of artillery. In this vignette, the most effective provider of close support was the MLRS-launched Damocles.

Sensors, Cueing, and Fire Control Issues:
What Contribution Would a Tactical Surveillance, Targeting, and Reconnaissance System Make to Battle Outcomes?

Given the conditions under which this engagement was fought, the advanced artillery systems came the closest to providing the needed close support. The target acquisition for all of the advanced artillery cases was provided by UAVs. The UAVs were capable of providing real-time BDA when targeting the armored formations for the firing batteries. This permitted the timely targeting of the most lucrative target arrays.

What Is the Value of the NLOS/FOG-M Target Observation (Sensing) Profile to Close Support?

The EFOG-M was very close to being the close support system of choice in this scenario. The relatively slow speed of the EFOG-M, when coupled with its large footprint, maximized its opportunities for engagement, permitting the timely targeting of the most lucrative target arrays. While not explicitly simulated, EFOG-M could selectively attack command and control assets or, depending on the anticipated form of supporting air attacks, suppress RED air defense assets.

Munitions Issues:
What Fixed-Wing Munitions Concepts Can Overcome the Inefficiency of Narrow Weapons Patterns in Current Munitions?

The clear message in our results is that a substantial increase in lethality can be achieved for fixed-wing delivery of the SFW if the dimensions of the pattern can be increased by a factor of four (an area increase of a factor of 16). This is essentially true even if the increase in pattern size is achieved by reducing the number of sub-munitions by 50 percent. While our results show that the number of SFWs that we employed achieved only about 50 percent of the required RED attrition, there are neither attrition constraints nor airspace considerations that would prevent employing twice the number of aircraft against this large ground target.

Can Current Fixed-Wing Systems (e.g., Maverick) Provide a Multiple Target Engagement Capability?

In the very stressing case where a mechanized regiment, protected by current mobile air defenses, had gone to ground on terrain of its choosing, the Maverick was not an attractive alternative. However, a multiple Maverick launch capability per pass would have potentially improved the capabilities of the Maverick. Even with an extensive SEAD campaign, though, the Maverick could probably not provide enough close support capability to turn defeat into victory for the ground forces in this vignette, because the defensive target posture presented by the enemy largely negated the missile's capabilities.

6. Implications for Future Close Support

Changes in the defense environment (which determines needs) and in technology (which determines capabilities) are combining to change the systems and employment concepts needed for close support. Taken together, these systems and employment concepts will shape the force structures of the future. But before that shaping can take place rationally, a number of key questions need to be answered. This study tries to shed light on two of these questions:

- How might the ground commander's needs for close support change in the future?
- What are the unique characteristics of systems that can meet these new needs?

This section of the report presents the study team's answers to these questions.

Critical Battle Situations Calling for Close Support

In order to understand future close support needs, our study team reviewed the planning documents and other guidance used by OSD and the Joint Staff to shape U.S. military strategy for the new defense era, assessed recent military experience, and analyzed possible future contingency scenarios. These assessments allowed us to identify a set of situations in which close support might be critical to successful battle outcomes. We have identified four:

- *Augmenting Allies*—situations in which the U.S. is relied on to provide close support to allied forces that are deficient in these capabilities and often have shortfalls in the doctrine, training, and equipment necessary to effectively interface with the U.S. forces providing such support.
- *Supporting Light Infantry*—situations involving the employment of light infantry forces either because of their appropriateness to the terrain or because of their ability to be rapidly deployed in a crisis.
- *"Leading Edge" Problems*—situations associated with the early stages of the buildup of U.S. forces in a contingency.
- *Supporting Mechanized Offensive Operations*—situations in which the U.S. has built up enough combat capability in the theater to exercise the initiative and conduct offensive operations in order to conclude the conflict.

To appreciate the close support needs of these situations more specifically, we selected and developed detailed descriptions of particular engagements that are representative of these critical battlefield situations. These are

Augmenting Allies

- Escort of a Humanitarian Convoy
- Support for an Allied Enclave

Supporting Light Infantry

- Small Unit Infantry Assault
- Small Unit Infantry Patrol

"Leading Edge" Problems

- Hasty Defense by Light Forces
- Prepared Defense by Light Forces

Supporting Mechanized Offensive Operations

- Armored Force Meeting Engagement

Using these vignettes as representative examples of the critical battlefield situations, we assessed how much and what kind of close support would be needed as a function of time to change battle outcomes.

Future Ground Commander's Needs for Close Support

Our assessment of the different battle situations suggested that the key components of the ground commander's needs were: How much close support is needed, What kind of targets must be serviced, and How much time is available to couple this close support into the battle?

Each of these could be measured in our analytic experiments in relation to the criteria for successful battle outcomes (expressed as BLUE survivability and RED force elements destroyed) that we established for our combat vignettes. We have measured "how much" in terms of the number of enemy targets that needed to be destroyed over and above those killed by the ground force, "what type" in terms of the kinds and posture of targets that need to be serviced, and "how quickly" in terms of how much time was available to apply sufficient close support to achieve a favorable outcome.

The findings are presented in more detail in Figure 6.1. It specifies whether or not improvements to the ground force could result in a favorable battle outcome (possibly eliminating the need for close support), whether close support could solve the problem (in some cases, no apparent practical technical solution appears possible for close support), how many kills are required, what type of targets need to be serviced, and how much time is available to do this.

	Solutions:			Needs:		
	Gnd Force	Close Support	Alternative Solution	How many kills required?	Of what types of targets?	In how much time?
Augmenting Allies						
Escort of a Humanitarian Convoy	no		avoidance, prevention, or retribution		Infantry in hide	
Support for an Allied Enclave		yes	interdiction	50	AFVs	25 min
Supporting Light Infantry						
Small Unit Infantry Assault	no	yes		44	Inf in barracks (32) Inf in towers (12)	3 min
Small Unit Infantry Patrol	no		avoidance, prevention, or retribution		Inf in multi-story buildings	
"Leading Edge" Problems						
Hasty Defense by Light Forces	no	yes	interdiction	150	AFVs	50 min
Prepared Defense by Light Forces		yes	interdiction	90	AFVs	30 min
Supporting Mechanized Offensive Operations						
Armored Force Meeting Engagement	no	yes		110	AFVs in defilade	50 min

Figure 6.1—Needs for Close Support in Different Battle Situations

How Much Close Support Is Needed?

The critical combat situations we analyzed can be grouped into four categories according to the need for close support in the battle vignettes we used in our simulations:

Close Support or Ground Force Improvements Could Meet Needs

- Support for an Allied Enclave
- Prepared Defense by Light Forces

Close Support Improvements Necessary to Meet Needs

- Small Unit Infantry Assault
- Armored Force Meeting Engagement

Both Close Support and Ground Force Improvements Needed to Meet Needs

- Hasty Defense by Light Forces

No Technical Improvements Currently Available for the Close Battle

- Escort of a Humanitarian Convoy
- Small Unit Infantry Patrol

The analysis resulted in three major findings concerning how much close support is needed:

Additional firepower is necessary for ground force success in many situations. The analysis demonstrates that substantial close support is essential to the success of the friendly forces in many of our vignettes. Battle outcomes were judged in terms of RED forces destroyed and BLUE forces surviving and measured against the success criteria we developed for the vignettes. These criteria were based on the specific mission, theater context, and follow-on mission needs for each

of the units involved in the vignettes. The series of cases the study team ran to examine how the "notional" close support would affect battle outcomes indicated that although ground force improvements could meet mission success criteria in some cases, close support could meet the success criteria in these cases and in a broader set of situations as well. In the least demanding of these situations, the ground commander needs to have between 50 and 90 armored fighting vehicles (AFVs) destroyed by close support within a half-hour timeframe to successfully influence the battle outcome. Improving the ground forces is an important option and is necessary for situations in which U.S. involvement (through providing close support) might be problematic or where close support is not capable enough by itself (for example, the Hasty Defense by Light Forces situation). In the most demanding of these situations, in which both ground force improvements and close support are needed, the ground commander needs to have between 110 and 150 fighting vehicles destroyed by close support in roughly one hour. In many situations (for example, the Small Unit Infantry Assault), the attrition of the BLUE force is prohibitively high when it is not provided close support, and the mission is not practical without additional firepower. In these situations, achieving the desired *level* of damage to the RED force is usually easy, but achieving the needed level of BLUE survivability will require servicing the right set of targets as well as improvements in weapons system characteristic. Our analyses also indicated that there was a set of battle situations (typically ambush situations) in which the needs of the ground force were so extreme that no technical close battle solution seemed practical.

Ground commander's needs in plausible situations can exceed envisioned future close support capabilities. In the Hasty Defense by Light Forces situation, two light infantry battalions require a lot of close support to hold against two heavy regiments. Both ground force improvements and substantial close support capability are needed. Alternatively, it might be more practical to consider shaping the battlefield by attacking the road nets that the heavy forces use to close with the light forces, or to interdict the heavy force elements themselves as they traverse the road nets.

The need to avoid/prevent ambushes is important in the new defense environment. Providing enhanced lethality for the ambushed force was shown to be of limited value by our analysis. Close support destroys elements of the force setting the ambush, but it has only a limited ability to lower friendly losses.

We do not see a "technology or firepower fix" for the ambush once it has begun. This statement was true for the Escort of a Humanitarian Convoy vignette and is even more imperative for the light infantry patrol in an urban environment.

This is the most stressful situation we studied. It is easy for the RED forces to employ, difficult for BLUE forces to counter, and results in a large numbers of casualties. These facts dramatically emphasize the importance of avoiding the ambush and hence the importance of battlefield information--not a "close support" need but an important requirement for the new defense environment. HUMINT could be quite beneficial in ambush avoidance. Remote sensing could also contribute valuable information. Shoulder-held weapons such as rifles and anti-tank rockets are in effect a dipole that, if detected remotely, could give warning of an impending ambush or could locate the members of the ambush team on their march to the ambush site.

The U.S. can not conduct many of the peacekeeping/peacemaking operations called for in the new defense environment without the ability to conduct routine urban patrols. The U.S. can not support humanitarian operations if it can not provide an adequate level of security to convoy operations. The ambush tactic provides what could be a dominant strategic advantage in countering U.S. forces in operations based on these two functions, if information warfare can not turn the tide.

What Types of Targets Must Be Serviced?

A mix of target types must be serviced to ensure favorable battle outcomes. In choosing how to provide this close support capability, an additional consideration is needed beyond level-of-effort considerations and timeliness of effect (kill rate and responsiveness). This consideration deals with kind and place.

For example, in our Small Unit Infantry Assault vignette, laser-guided bombs were needed in all cases to take out the immediate reaction force (IRF) barracks and initiate the assault. Both NLOS/FOG-M and attack helicopters were effective against the towers. Additionally, attack helicopters are the most effective system for dealing with vehicular targets from armored quick reaction force (QRF) and local air defenses. This is because the attack helicopters were able to acquire the reaction force vehicles well before they arrived at the scene of the assault battle. Thus, the posture of fighting vehicles (on the march, in the attack, or in defilade) serves to distinguish distinctly different types of targets that need to be serviced to change battle outcomes. Our analysis of the value of targeting information in the Support for an Allied Enclave situation illustrated the value of being able to service these different target configurations as they present themselves over the course of the battle. This also has implications for munitions footprints and attack endgames (e.g., in our Armored Force Meeting Engagement vignette, this favored munitions with a high angle endgame geometry).

Although AFVs still remain a key type of target in future critical battle situations, ground commanders will need to have a range of different target types serviced because of the more varied forms of combat associated with the new defense environment.

Discriminative retribution may have deterrent value. Our ambush vignettes illustrated that individual members of an ambush team constitute a class of target that probably will not be serviceable within the extremely short timeframe required. Our analysis suggests that U.S. forces can find and kill the ambush team after an event even though they can not prevent or abate the ambush losses with close support. As a result of this analysis, we argue that the U.S. should develop the capability to avoid ambush situations through reconnaissance, warning, and other capabilities. If avoiding the ambush is not possible, the threat of retribution may deter individuals from taking part in future ambushes. This is not a preferred strategy, however, as the limited conflict literature is replete with discussions of the negative implications of indiscriminate retribution. Some form of marking, designating, or tagging the individuals involved in the ambush might be useful so that they could be identified or detected subsequent to the actual ambush. Research into sensing, target discrimination, and marking might prove to be beneficial.

We need to inform the employment of close support systems and the ground force so they can serve the right types of targets. Our situation assessments suggest that there is an important payoff to serving the right target at the right time. Given that the study team's analysis was oriented toward finding "firepower" answers, these "information" insights are perhaps all the more notable. This value of battlefield information was particularly apparent in two of our vignettes.

The Support for an Allied Enclave vignette demonstrates the payoff for engaging the right elements of the adversary's force. In this case, the enemy attacked from several points on the compass, allowing the geometry of the battle to clearly illustrate the need to service the right targets in the right location. The relatively few launchers used by the allied defense in this vignette, complemented by a command and control system that was capable of quickly tasking the engagement systems to fire at targets in alternate and secondary sectors of fire, enhanced the defender's survivability by roughly 10 percentage points.

A second example of this was shown by the improved survivability of the BLUE force in the Prepared Defense by Light Forces vignette. This vignette demonstrated the value of using adaptive targeting information when a series of simulation experiments showed that the "best notional close support case" results were not as favorable to the defenders (in terms of their survivability) as were the results of the case in which Damocles was provided adaptive targeting by UAVs orbiting over the target. This apparent anomaly was caused by the fact that in the notional close support case, RED battalions were removed from the scenario without knowledge of which RED units would be most damaging to BLUE as the battle changed over time in response to close support.

The improved survivability of the BLUE force that results from the proper targeting information is also illustrated by a comparison between the cases that employed adaptive targeting and those that used perfect prebattle information. In the perfect prebattle targeting information cases, all launcher loads were fired early in the battle and then followed by volleys at 10-minute intervals (to allow for reload). The initial volleys quickly destroyed the targets that would have been the most damaging to BLUE if there had been no close support. This resulted from attacking the high-value formations as they first came into range, but these were not necessarily the most critical targets in the battle that developed once this close support began to influence the battle. When the UAVs provided the adaptive targeting information, they metered the expenditure of rounds fired so that launchers were attacking critical targets continuously throughout the engagement. This also resulted in an improvement in the BLUE force survivability of about 10 percentage points.

How Much Time Is Available to Provide This Support?

The time available to usefully couple close support into the battle in the critical combat situations we examined ranged from 3 to 60 minutes depending on the situation. Some of the critical battle situations we examined, such as the ambushes vignettes, present such extreme requirements for making the full impact of close support felt on the battle that we argue that other solutions must

be found. In these cases, the effect must take place before the ambush team begins firing. Our analysis underscored three major points on the time available:

Responsiveness is a key requirement for close support, but it must be complemented by other capabilities to have a decisive impact on battle outcomes. The short duration of many of our vignettes makes responsiveness a key requirement for close support. But time itself does not completely define the issue. If the close support system is not available when the engagement begins, the rate at which it must destroy targets must increase. This is because the time available to affect the battle is shortened by the length of the delay, and the number of targets that must be serviced by close support will either remain the same or increase.

In some of the combat situations we examined, the time available to do the job was extremely short. For example, in our Small Unit Infantry Assault vignette, the six guard towers and the IRF barracks must be destroyed within 3 minutes. While this is a stringent requirement, it is well within the capabilities of current systems employed in a coordinated manner by well-trained crews.

All of the systems we examined could be employed in ways that make them responsive. But such employment tactics must also be practical in light of the overall operational situation. The initial application of force in the Small Unit Infantry Assault vignette (just described) is practical in a context of that operation (it is preplanned and the U.S. has the initiative). On the other hand, while dedicated fixed-wing or attack-helicopter assets flying "CAP" might provide a sufficiently timely response in the convoy escort vignette we examined, doing so may not be practical. This is because a contingency force must be able to provide this level of protection for each situation in which close support could be called for, and providing a dedicated CAP over the majority of humanitarian convoys in a major operation could be impractical. Advanced artillery support would require an extensive, detailed fire-coordination plan, real-time communications, and timely movement of the fire units or a fire support base system that might be in conflict with larger considerations in a humanitarian support situation.

Responsiveness, then, is better characterized by the level of target servicing (kills per minute during the battle) that can be guaranteed to each potential battle situation that needs close support, rather than by the time it takes to deliver close support fires to the battle.

We need a greater kill rate than most current systems provide to effect favorable battle outcomes. In the least demanding of the critical combat situations we examined, between 50 and 90 AFVs had to be destroyed by close support within a half-hour to successfully influence the battle outcome. In the most demanding of these vignettes, between 110 and 150 fighting vehicles needed to be destroyed by close support in roughly one hour. This is beyond the capabilities of our current systems and even taxes the proposed systems we examined.

The simulation results in our Prepared Defense by Light Forces vignette demonstrate that larger-footprint munitions (Damocles) were much more effective against moving armored formations than were smaller-footprint munitions (SADARM). This finding provides evidence that the

increased killing rate associated with the larger-footprint Damocles sub-munitions was needed to produce the favorable battle outcomes we were looking for.

The notional close support in our Support for an Allied Enclave vignette found that we needed to eliminate as many as 60 AFVs from the attack to meet the success criterion for the BLUE forces in the vignette. To kill this many targets with real-world systems when faced with the confined airspace in the vicinity of an enclave will require multiple AFV kills per pass. Our work with wider, or adaptive, footprint fixed-wing munitions that better match the target arrays presented in the battles we examined suggests a similar message--to achieve the kill rates needed to turn the battle, a higher kill rate is needed for close support systems than current systems provide.

Desirable Characteristics of Systems to Meet Future Close Support Needs

We used this analysis of critical battlefield situations and the close support needs to determine what characteristics future systems should have in order to most effectively provide this capability to future ground commanders.

System characteristics can be thought of as enabling two fundamental functions that need to be carried out in providing close support. These are closing with the enemy (this includes surviving during this phase of the mission and closing with the right enemy) and engaging the enemy successfully (this again includes surviving this phase of the mission, as well as acquiring and destroying the right targets). While our initial focus was on platform characteristics, we found that many of our desirable characteristics focused on munitions, sensors, and information. In a number of cases, the systems needed to provide the information would more logically be part of the overall close support system rather than the fixed-wing, rotary-wing, or advanced-artillery platform.

The desired characteristics for future systems are summarized in Figure 6.2.

Vignettes	Solutions: Gnd Force	Close Support	Alternative Solution	Desired Characteristics:
Augmenting Allies				
Escort of a Humanitarian Convoy	no		avoidance, prevention, or retribution	Surveillance Moving into position In hide
Support for an Allied Enclave		yes	interdiction	Wider / adaptive footprint anti-armor munitions for fixed wing Sensors to target pre-assault assembly Info / Wpn sys to effect "virtual" redeployment of ground forces
Supporting Light Infantry				
Small Unit Infantry Assault	no	yes		Info system to enable multiple systems employment Insertion team employed close support system Man portable FOGM
Small Unit Infantry Patrol	no		avoidance, prevention, or retribution	Sensors capable of detecting ambushers In hide in urban environment
"Leading Edge" Problems				
Hasty Defense by Light Forces	no	yes	interdiction	Fixed wing munitions that allow high kill rate Wider, or adaptive footprint Higher multiple kills per pass
Prepared Defense by Light Forces		yes	interdiction	Same as for hasty defense Arty munitions that allow high kill rate Wider, or adaptive footprint Higher multiple kills per salvo
Supporting Mechanized Offensive Operations				
Armored Force Meeting Engagement	no	yes		Fixed wing & arty sensors / munitions capable of top attack Info sys to pass gnd cmdr's intentions to close support force

Figure 6.2—Desirable System Characteristics Depend on the Battle Situation

Note that the "vignettes column" and the three columns listed under "solutions" are the same for Figures 6.1 and 6.2. The two figures differ in that the right three columns of Figure 6.1 show the commander's close support needs in terms of the number of kills, types of targets, and how quickly they must be killed. The right column of Figure 6.2 shows the characteristics that would be desirable in future close support systems.

Fixed Wing

Current fixed-wing systems have their greatest strength in their ability to carry large payloads over long ranges, a capability significantly greater than that of other close support systems. However, our analysis and previous work show that, except when carrying the most recently developed anti-armor cluster bombs (the SFW), current fixed-wing aircraft can not destroy armored targets quickly enough to have an important impact on the tactical battles expected in major contingencies.[1] They are constrained by target acquisition and munitions effectiveness, despite their large payloads.

Survivability is a consideration mainly in that it shapes the engagement windows within which fixed-wing aircraft must work. Signature coupled with speed affects survivability, as does suppression of air defenses, but these predominantly control attrition during penetration, not during an attack. Penetration attrition is important for fixed-wing missions such as interdiction but is less so for close support, except in circumstances where support is being provided to deeply inserted forces.

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[1]Callero, Don, and Frostic, *1993*.

Sophisticated aircraft designs rely on standing off, outside or above the target area defenses, to control attrition during an attack. Thus, these designs demand long-range target detection/recognition capabilities. Contemporary target detection systems also provide a measure of night/all-weather capability. Uncomplicated aircraft designs relying on unaided visual acquisition in clear-weather, daytime conditions would need to be produced for a small fraction (one-tenth to one-quarter) of the cost of sophisticated designs in order to be as cost-effective. This is because they have to expose themselves more to terminal threats to do their job. These designs may rely on protecting vulnerable areas (through hardening against piercing rounds, for example) to offset some of this disadvantage, but such hardening would be of little effect if the aircraft encounter air defense systems with larger warheads (which rely on blast as the kill mechanism).

The more sophisticated designs (which are likely to be more cost-effective although more costly) require working at longer slant ranges and within a limited engagement "window"—the time typically available between current onboard sensor acquisition ranges and when an attack must be broken off to avoid the most densely defended part of the target area. This implies a high value for aided target nomination, point and shoot deliveries, and cluster munitions that can autonomously acquire targets within well-defined footprints. Successful development of these capabilities would work to lift the kill rate constraint that currently limits fixed-wing systems.

Such lethality improvements will, however, need to take into account the wider range of target postures the U.S. will be faced with in the new defense environment. For example, in our Armored Force Meeting Engagement vignette, the contrast between the long-range standoff employed in the "lofted" delivery tactic of the SFW and the 7-kilometer standoff for the Maverick missile shows that the maximum standoff at which no significant degradation lethality occurs is the best for the fixed-wing survivability/effectiveness tradeoff. In this case, the in-defilade posture of the enemy severely degraded the advantage the Maverick would be expected to have in this situation because of its engagement range. However, this target posture calls for a high-angle endgame for the engagement. Thus, no amount of aided target nomination or other improvements designed to increase the missile's engagement rate would improve its performance in this scenario. As this illustrates, choosing how to incorporate desired characteristics for future fixed-wing systems will require assessing their performance in a broader range of engagement situations.

Our analysis of the Hasty Defense by Light Forces vignette provides a basis for identifying a deep-attack capability as a desirable characteristic for all close support systems (not just fixed-wing aircraft). An analysis of some basic factors influencing the contribution that speed, signature control, and sensors make in cost-effective accomplishment of deeper-attack missions noted that these system capabilities also serve to enhance close support effectiveness. As a result, we find no basis to distinguish between the signature, speed, and sensor suites that would be desirable for canonical close support, close support for deeply inserted forces, and deeper-attack or interdictive missions against enemy forces. A capable attack aircraft is necessary for all of these missions.

In many cases, SFW effectiveness was limited by both the dug-in posture of the adversary and the limited ability of the aircraft to line up the long, narrow SFW footprint with a linear axis of the target vehicle formations. Since weapon-pattern/target-pattern matching is one of the primary determinants of munitions effectiveness, our assessment of the SFW's overall effectiveness is lower than that usually found in studies that make less realistic assumptions about the tactical situation and employment.

Despite this, the analysis of of the Support for an Allied Enclave and the Armored Force Meeting Engagement vignettes indicates that a possible way to provide the needed close support capability would be to employ the SFW using a standoff, lofted delivery. The multiple-kills-per-pass capability comes close to providing the needed lethality in the required time, and the endgame geometry is right. However, as indicated by the analysis of this combat vignette, improvements to weapons footprints, particularly those that allow the sub-munitions to better match the target geometry, are needed.

Rotary Wing

The ability to hover provides helicopters a unique engagement mode that offers substantial lethality and good survivability. This marks helicopters as one of the most capable systems for providing close support in defensive combat situations despite their payload limits vis-à-vis fixed-wing aircraft. When supporting forces in a defensive posture, helicopters typically conceal themselves behind cover and wait until the tactical situation develops. When the enemy exposes itself during the attack, they then "pop up" to engage the tanks and AFVs outside the range of their armament. However, with many current weapons (laser-designated Hellfire or wire-guided TOW missiles), helicopters often can not continuously guide missiles during their entire time of flight (about 40 seconds) without being engaged by the enemy's longer-range (typically air defense) systems. As a result, helicopters frequently need to abort their engagements and remask to counter the enemy's air defense missiles. (They have the time to do this because of their standoff distance.) This attrition-management technique constrains the lethality of helicopters in providing close support in defensive armored combat.

In this situation, attack helicopters are constrained in lethality, not survivability. To counter enemy defense systems and enhance their ability to provide close support, helicopters require systems that will allow faster acquisition and launch rates so they can operate within the limited engagement windows available to them. Fire-and-forget anti-armor missiles and rapid target acquisition and cueing systems (such as those that the Longbow radar and fire control system provide) have the potential to allow many more targets to be engaged per pop-up during intensive mechanized battles and provide substantial increases in close support firepower. These conditions are typical of our Prepared Defense by Light Forces vignette, and the substantial existing and planned future capabilities of attack helicopters in this type of battle were the primary reason we did not assess helicopter employment in this vignette.

However, in battle situations in which helicopters can not roughly locate the air defense systems and stand off outside their defense envelope, these system characteristics pay lesser dividends.

Unfortunately, a poorly defined threat environment is characteristic of many of the critical battlefield situations we examined in this analysis. A number of these involved mobile threats (including AFVs with armament and fire control systems capable of engaging helicopters) or man-portable air defense missiles.[2] Additionally, these combat situations were characterized by a need to acquire and engage a wide set of target types, including troops and defensive structures.

In this new defense environment, additional battlefield considerations shape the helicopters' ability to be employed effectively, because in many of our critical combat situations, the targets are not exposed armored vehicles and helicopters can not engage from safe positions. The enemy's defilade posture in the Armored Force Meeting Engagement vignette limited attack helicopter effectiveness substantially. Helicopters could not be used in the Hasty Defense by Light Forces vignette, because there were no positions from which to engage the enemy safely and effectively; and they could not be used in the Support for an Allied Enclave vignette, because the enclave was surrounded by a dense enemy defense deployment and the enclave itself was subject to heavy artillery fire.

Helicopters were ineffective in acquiring the enemy in the urban environment in which our Small Unit Infantry Patrol ambush took place, but in our simulation results for the Escort of a Humanitarian Convoy, the four helicopters that arrived on the scene 10 minutes after the start of the ambush detected 23 of 24 members of the ambush team as they egressed from the area. This implies that present sensor technology may satisfy the close support requirement after the ambush.

In the Small Unit Infantry Assault, when BLUE could choose the time and place of engagement, low-observable signatures and munitions capable of destroying bunker-type targets were important to mission success. The ability to carry internal stores reduces the helicopter signature as well as the drag. These two characteristics are each important when an attack helicopter has to penetrate a long distance into hostile air defenses to support a special assault. Since all of the enemy environment harbors potentially deadly air defense that has not been alerted, reduced signature and increased loiter capability are essential. Lethal bunker- and building-buster munitions were necessary for the helicopters to successfully provide close support to the assault team.

Noting that attack helicopters have a substantial capability in battles like our Prepared Defense by Light Forces vignette, we will focus on those combat situations in which the helicopter promises significant advantages over other systems as the most lucrative area for future enhancements. These situations are best exemplified by our ambush vignettes and the Small Unit

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[2]As of this writing, U.S. helicopters have not experienced a man-portable air defense missile threat since the Vietnam conflict, when six attack and assault helicopters were lost to the SA-7, a man-portable surface-to-air missile. (The U.S. helicopters lost in Somalia were lost to unguided, rocket propelled grenades.) Soviet helicopters in Afghanistan significantly modified their employment tactics (using much higher altitudes for ingress and attack with subsequent impact on their effectiveness) once Stinger missiles were introduced into that conflict.

Infantry Assault. As a result, enhancing the ability to preclude or, failing that, to respond to ambush situations by improving helicopters' ability to detect any unique signatures presented by an ambush team would appear to be an important approach to meeting a critical future battlefield need. Additionally, ensuring that some portion of the attack helicopter force has the low-observable signatures and munitions capabilities required to support the special unit assault team promises to provide need capabilities to an important type of mission that may need to be supported in the future.

Advanced Artillery

Previous analysis has shown that although current artillery systems are highly effective against exposed infantry, they are only marginally effective in defeating armor, despite their very rapid response times and long "loiter" time.[3] Effective anti-armor munitions for artillery are currently under development,[4] but these are not likely to meet future close support needs well due to two constraints. First, while sub-munition lethality against armored targets for these weapons is very good, the weapons' footprints are either too small or too large for dispersed, moving targets close to friendly forces such as those found in many close support situations in mechanized battle.[5] Our analysis suggests that munitions concepts (such as those based on terminally guided sub-munitions or those with modest footprints) can be just as cost-effective as those under development for deep fires and interdiction employment and are more consistent with close support employment.

Some inherent characteristics of artillery can dictate that it is the only practical asset to use in some circumstances. For example, the high angle trajectory of the advanced artillery gives it a distinct advantage over fixed-wing aircraft or attack helicopters using low-altitude attack profiles (due to the enemy air defenses) in some situations. In our Armored Force Meeting Engagement vignette, where the RED force took up a position in defilade on the high terrain overlooking the BLUE approach paths, this proved a critical capability as artillery was by far the most effective system in these circumstances. The possibility that artillery is the only effective asset for some circumstances underscores the need for effective close support munitions for artillery.

Second, while the munitions concepts based on sensor-equipped sub-munitions represent a highly cost-effective solution to the needs of mechanized combat, they lack the flexibility to handle targets other than armored vehicles—particularly the wide range of targets found in light

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[3]Callero and Veit, 1993.

[4]Two examples of these are the SADARM (Sense and Destroy Armor) and the BAT (Brilliant Anti-Tank) smart artillery sub-munitions efforts. The former, designed primarily for a counterbattery role, uses an explosively formed penetrating slug. Because of the limited range of this slug, the weapon has a footprint that is too small to be effective in close support. BAT, designed primarily for deeper fires, uses aerodynamic forces to give the sub-munitions substantial reach but has been designed with too large an area of regard for targets close to friendly vehicles (at least until the development of mature and trusted target identification capabilities that would insure these sub-munitions would not attack friendly vehicles).

[5]Matsumura, Hinton, and Halverson, 1994.

infantry combat, such as bunkers and firing positions in buildings. Artillery systems based on fiber-optic guidance can provide the flexibility to handle a wide range of targets because the television guidance they employ allows the gunner not only to attack armored targets, but also to engage other types of targets.[6] Such systems, however, have had uneven development support and have been slow to be fielded in the U.S. because they do not match well with current inter- and intra-service proponency.

The Small Unit Infantry Assault vignette illustrates that a need exists for a small, light (nominally 60-mm) mortar that, together with enough ammunition, can be man-carried into battle over a considerable distance in bad terrain. The accuracy of the sensing/guidance is essential to accomplishing this mission. Point targets need to be destroyed quickly by a few rounds that can be man-carried into the engagement. The round will require enough lethality to allow it to destroy point targets such as weapons towers, hardened bunker facilities, and moderate-sized, lightly constructed buildings using only a reasonable quantity of ammunition.

Deployability distinctions among close-support-capable systems are often commonly supposed to be driven by platform weight, and artillery is often viewed as less deployable than other systems. However, our analysis shows that deployability is in fact driven by system lethality. Smart anti-armor sub-munitions imply more kills per fire mission; this in turn implies providing a given level of combat capability with fewer systems deployed. A careful accounting of the lift required to move a given level of close support capability (measured in enemy vehicles killed during the first battle) into theater reveals that once equipped with such munitions, advanced artillery systems may be just as deployable as air systems.

Our analysis suggests that small, deployable packages of advanced artillery can have a significant effect on battle outcomes. In the Small Unit Infantry Assault vignette, the "small deployable packages" were based on a 60-mm mortar firing a fiber-optic guided round. These could be carried into the engagement by the support force. The mortars made a substantial contribution to the satisfactory completion of the mission. In the Prepared Defense by Light Forces vignette, "small deployable packages" were based on the MLRS and comprised one battery of nine launchers. As our analysis of this vignette showed, the single battery was able to change the battle outcome, meeting the success criteria for the vignette.

Despite the substantial promise of advanced artillery systems, they are not a general solution to the close support challenge. Our analysis indicates that the urban environment imposes substantial limitations on artillery employment. This includes limited locations from which to employ advanced artillery (the Support for an Allied Enclave vignette) and concerns about collateral damage and weapon effectiveness in a built-up environment (the Small Unit Infantry Patrol). We could identify no practical characteristics of advanced artillery systems that could realistically eliminate these limitations.

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[6]Steeb et al., 1994.

Sensor and Targeting Systems

The analysis of many of our vignettes provided valuable insights concerning the desirable characteristics of tactical battlefield information systems. Discovering information-based answers while looking for firepower-based systems' characteristics makes the insights concerning battlefield information systems all the more notable.

The analysis of the vignettes associated with the Escort of a Humanitarian Convoy and the Small Unit Infantry Patrol suggests that the best strategy for defeating an ambush is to avoid it. This strategy depends on battlefield information. In the ambush situations, airborne vehicles, particularly helicopters, seem to have the most promising inherent characteristics to address the problems inherent in these combat situations. Platforms will need an elevated and mobile observation position and perhaps an ability to hover, and must move at a speed compatible with the force they are supporting. Available munitions seem more than adequate for the job in the convoy escort situation (and probably in the patrol situation, if collateral damage is not a great concern). The key problem is one of target location and detection—particularly detection in advance of the ambush—not of platform capabilities or munitions effectiveness. As a result, improved sensor technology is required to cope with the ambush situation. To be effective, sensors will need to be able to warn of the impending ambush *before* the operation begins and to handle concealment—either foliage or buildings. The ambush tactic can provide U.S. adversaries with what could be a dominant strategic advantage. The ability of the U.S. to intervene in peacekeeping and peacemaking situations may rest on the success of this technology development.

The Support for an Allied Enclave analysis explicitly shows the potential contribution of information systems when used to dynamically inform the employment of the ground forces to complement the effects of close support. In this vignette, we found that there was an important payoff to being able to allocate the defense forces (infantrymen with limited tactical mobility in this case) to leverage the effects of close support.

In the Prepared Defense by Light Forces vignette, we observed that weapon footprints have to be large enough to accommodate the assault formations of the mechanized attacking force that occur during various stages of the attack. If this effectiveness improvement is to have its greatest payoff, the systems supporting such defensively postured light infantry also need an all-aspect engagement capability to compensate for the lack of tactical mobility that typically limits these forces. Survivable UAVs proved particularly useful in this scenario due to the limited observation positions available to infantry forces defending against armored forces and their ability to provide information in an adaptive way as the battle developed. The combination of effective munitions and targeting systems able to adapt to a changing battle situation (as the effects of close support influenced the battle) had a significant effect on improving battle outcomes. The effect was so pronounced that the defending force was able to meet the success criterion for this engagement.

Future Shock: Changes in Fighting Concepts May Change How We Think About Close Support

Because of rapid changes in technology and in the defense environment, it is possible that fighting concepts will change dramatically over the next decade, blurring the distinction between close support and close battle. Based on the experience of the study team in this analysis, our assessment is that these two sources of change could reshape the ways the U.S. conducts operations on the battlefield to such an extent that current thinking will be obsolete. What is currently termed close support may simply be viewed as an example of the way in which all distributed engagement systems are employed. For example:

- As we have previously reported, the Escort of a Humanitarian Convoy, Small Unit Infantry Patrol, Support for an Allied Enclave, and Prepared Defense by Light Forces are all vignettes which showed a high payoff for information. As this aspect of combat becomes more appreciated, the use of such systems may change fighting concepts in the close battle.
- For mechanized battle, fighting teams working in "eyeball" and "shooter" pairs (e.g., UAVs paired with artillery systems) may replace today's close battle units, which may in turn become operational reserves used for "mop up" operations. Since many of the primary engagement systems in such concepts are currently considered close support assets, such changes in fighting concepts may beget important changes in whether such a mission is even recognized as distinct from simply engaging the enemy—what is now considered close support may become an integral part of close battlefield operations.
- If reconnaissance and communications systems capable of battle situation assessment and targeting were available in the light infantry battle, very different fighting concepts might be possible. In such concepts, essentially all of the firepower used by infantrymen might be provided by remote systems. Such changes could make what might currently be thought of as close support systems an integral part of the light infantry fighting unit and could require substantial change in the light force structure and who provides it. The need for substantial change may be already here. Today's capabilities allow U.S. forces to detect infantry and fix them in place with air or artillery attacks, but it is still necessary for U.S. infantry to close with the enemy to finish the battle at close quarters. Currently the Army and the Air Force have little capability to actuate their commonly agreed-to war-fighting doctrine in this form of combat—the lack of reconnaissance and surveillance systems that can detect and target infantrymen precludes U.S. forces from decisively engaging the enemy before being joined in close battle (unless significant collateral/civilian damage is acceptable).
- Finally, entirely new "fighting" doctrines may develop to accommodate "peacemaking" operations. We have already seen the confluence of close air support and operations other than war—a combination that nearly everyone would have found difficult to conceptualize only a few years ago. Among other problems, such a combination adds complexity to the mission and introduces new players in the conduct of the mission. In Bosnia, for example, the dual chain of command required that both NATO and the UN approve a request for close air support before the mission could be flown.

Appendix A
Scenario Assessment

In order to assess the kinds of challenges that future contingencies might present the U.S., we designed an analytic process that would allow us to derive from a broad range of potential scenarios the critical battlefield situations that were important to combat outcomes and thus appropriate for close support analysis.

The theater-level scenarios we developed for this assessment included the following:

- A light force contingency in the Americas
- A light force contingency in Central Asia[1]
- A major contingency in the Far East
- A major heavy force contingency in northcentral Europe
- A major heavy force contingency in Southwest Asia
- A peacekeeping contingency in the Balkans[2]

A Delphi Approach to Scenario Assessment

Because this set of scenarios formed the basis for combat simulation assessments, each of which requires substantial time to develop, the specific situations were carefully selected rather than chosen randomly. Our approach to assessing these scenarios had three steps:

- Identify the fundamental characteristics that define and distinguish different scenarios and define the "scenario space."
- Determine how well our scenarios cover the appropriate regions of this space and refine the scenarios as necessary.
- Determine which battlefield situations within these scenarios were important to combat outcomes and thus to close support analysis.

To aid us in this process, we have relied on the concept of scenario space and on an analytic technique to foment expert consensus known as the Delphi method.[3]

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[1]This scenario, dealing with instability in the Republic of Georgia, was originally included in the analysis. As actual events came to closely match the hypothesized situation described in the scenario, the scenario was dropped. This was due to the complications associated with conducting weapons system analysis in the context of an unfolding real-world political/military situation, and our judgment that we could capture most of the considerations in our peacekeeping and light force contingency scenarios.

[2]This scenario was initially considered as a major contingency in the Balkans. After the Delphi deliberations, it was decided that a peacekeeping contingency was more suited to our needs.

[3]Dalkey, 1971.

The Concept of Scenario Space

To understand what characteristics are desirable for systems that can provide close support in the new defense era, we need to test candidate systems against the full range of situations they may be called upon to deal with. We have chosen to rely on the *fundamental characteristics* that define and distinguish different scenarios, such as distance from the U.S., terrain, and opposing forces, as a means of insuring we consider truly different battlefield situations over a sufficiently broad range. In doing so, these characteristics could be thought of as defining the *scenario space,* the collection of potential future scenarios in which U.S. forces might be employed. Thus, each specific scenario in this space is described by its unique fundamental characteristics.[4] Given this as our analytic construct, the operative question is, How can we actually characterize the scenario space and compare one scenario to another—in short, What are the specific characteristics defining this scenario space?

Using Fundamental Characteristics to Define Scenario Space

Our study enjoyed the advantage of being able to rely on a previous research effort undertaken as a "capital building" project at RAND. That study probed the question of what fundamentally distinguishes situations in warfare. As a result of our extensions to this analysis, the following characteristics were developed as being those that, when taken together, would largely determine the outcome of a conflict:

Terrain
Weather
Deployment Distance
Strategic Choke Points
Air Infrastructure
Ground Infrastructure
Operations with a Coalition
Time Available to Respond
Air Threat Sophistication
Ground Threat Sophistication
Threat Size
Nuclear Weapons
Biological Weapons
Chemical Weapons

These characteristics are defined and discussed in detail below. In the next subsection, we describe the way in which we used the characteristics and the scenario space they define to insure the adequacy of our selection and development of scenarios (and the specific battlefield situations found therein).

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[4]Davis and Finch, 1993.

The Delphi: Refining Scenarios and Ensuring That We Realistically Cover the Scenario Space

To conduct the scenario assessments we needed to know how well the 14 characteristic dimensions defined the scenario space, where in the space a particular scenario lay with respect to these dimensions, and how well we covered the region of concern. With regard to a particular characteristic, "covering the region of concern" means "how well do the scenarios describe the entire range of values from the worst conditions to the best conditions?" To develop this understanding, we needed a method for comparing scenarios along each of the characteristic dimensions; we selected a technique for eliciting and refining the group judgments of functional experts, known as the Delphi method. It has three features. The opinions of the members of the group are obtained in such a way that the responses are anonymous. Iterations are obtained by conducting systematic controlled feedback between decision rounds. Group opinion is defined as an appropriate statistical aggregate of the individual opinions in the final round. These features are intended to minimize the effects of dominant individuals, irrelevant communications, and group pressure encouraging conformity.

The Delphi methodology was developed at RAND in the mid-60s, has been further developed in the published works of Helmer, Dalkey and others, and was used extensively at RAND and in other corporate settings for forecasting technical, social, and economic futures. Some of the limitations of the approach are associated with the difficulty of picking enough real experts to provide statistical significance.[5] In addition, the dropout rate tends to be high because many people underestimate the time and commitment required to complete the process. Each of these limitations played a part in our use of the Delphi methodology.

To address the issue of how our scenarios covered the scenario space and what modifications we needed to make to improve this coverage, we conducted a Delphi experiment with a group of defense analysis and scenario development experts at RAND. We presented them with written descriptions of the scenarios and asked them to evaluate the implications of each characteristic for each scenario. We gave them each a detailed description of what the scoring range from one to ten meant for each characteristic.

A Summary of the Findings

The Delphi methodology provided sufficient convergence that we could use the measures of central tendency to characterize the various scenarios and measure how well they in fact "covered the scenario space."

The next step was to identify various stages of the battle situations that occurred frequently across the group of scenarios and that could be construed as being representative of the needs for future close support.

Using a group of experienced military operations analysts, each of whom had prior military service, a "map exercise" was run on each scenario. In these exercises, deployment, operational concepts, and the evolution of the campaigns' engagements as a function of time were developed. Based on this detailed understanding of the scenarios, an assessment of recent combat experience, and previous detailed analyses of close support in armored warfare, we have chosen a set of battle situations in which close support might prove critical to battle outcomes because of

[5] Sackman, 1974.

the relative weakness of the U.S. and allied forces. The team found that the scenario analysis validated the findings of the two previous stages (the review of defense strategy and guidance, and the analysis of recent U.S. military involvement):

- *Supporting Allied Forces*—situations in which the U.S. was relied on to provide close support to allied forces that were deficient in these capabilities and often had shortfalls in the doctrine, training, and equipment necessary to effectively interface with the U.S. forces providing such support.
- *Supporting Light Infantry*—situations involving the employment of light infantry forces either because of their appropriateness to the terrain or because of their ability to be rapidly deployed in a crisis.

It also added a third category of critical battlefield situation in which close support might be critical to battle outcomes:

- *"Leading Edge" Problems*—situations associated with the early stages of the buildup of U.S. forces in a contingency.

The next subsection explains our approach and findings in detail.

Experimental Design for the Delphi

As explained in the subsection outlining the study's approach to scenario and battlefield situation development, a Delphi experiment was used to examine how well the scenarios outlined above covered the "scenario space" that we found important in close support analysis. We also used it to suggest improvements to the scenarios and to provide additional insights as to which battlefield situations within these scenarios were the most important for this analysis.

What Defines and Distinguishes Future Scenarios

As explained previously, we have chosen to rely on the fundamental characteristics that describe and distinguish scenarios to define the scenario space we believe is important to regard for future defense analysis and, particularly, for the analysis of close support systems. The characteristics can be grouped into three categories: unlikely to change, potential for change, and likely to change.[6]

The first of these categories is essentially self-explanatory since the geography and location of the scenario set these characteristics. In fact, the need for different scenarios has been driven by a desire to cover a range of these types of characteristics. The second set of characteristics has some potential for change, particularly in the intermediate term as (for example) air bases or port facilities are constructed. The third grouping has scenario characteristics that are likely to be treated as variables in an analysis, because (for example) a range of warning times are plausible. The concept of using very different wars within a particular theater as a means to more efficiently

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[6]In assessing where a particular scenario stands in the scenario space, we have adopted the convention that awards higher scores for situations that represent an advantage for the U.S.

explore a range of the "scenario space" (e.g., with quicker, lower-cost setup time) matches well with this last group of characteristics.[7]

The Delphi was organized around a question concerning where each scenario fit with regard to the fundamental characteristics that describe and distinguish scenarios. Just as important to us was knowing the rationale for why the participants chose the ratings they did. Unfortunately, the scenario "Strife in the Balkans" was added to the study after the Delphi experiment was completed. We could not find an acceptable means for obtaining "Strife in the Balkans" results to include with the rest of the Delphi results.

It is perhaps easiest to describe the Delphi question, and what is represented by the score the Delphi participants provided, in the following paraphrase: What is your measure (from one to ten) of the U.S. ability to deal with the problems presented by *terrain* (for example) in this scenario. A scenario might score high or low based on U.S. capabilities or based on the size of the problem to be overcome. The assessment is a judgmental product of these two dimensions (problem size and level of U.S. capabilities). For each combination of scenario and characteristic, we plotted a frequency diagram of the response. We discuss each of these characteristics in detail below.

Characteristics That Are Unlikely to Change

Any scenario, by virtue of its taking place on (or near) the surface of the earth, has characteristics that can not be readily controlled by either of the adversaries—terrain, weather, deployment distance, and strategic choke points. Given the departure from the canonical NATO/Warsaw Pact scenario that has taken place recently, and the fact that the U.S. for all its technology can not change these characteristics, we must explicitly consider how U.S. forces will cope with them.

Terrain. Terrain has an important effect on combat operations in that it importantly influences the type of forces that are most appropriate for the conflict. If the terrain favors the use of weapons systems for which the U.S. enjoys an advantage over the adversary, the relative influence of this characteristic for a given scenario would be higher. Terrain should also be considered in the context of risk to U.S. forces. Even though the U.S. has weapons suited to the terrain, certain types, such as jungle or urban, involve an inherent risk during combat operations.

There are many potential quantitative measures of the physical characteristics of a given set of terrain. What these measures can not do, however, is provide a "net assessment" of whether this terrain provides a relative advantage for the adversary or presents problems that the U.S. has a good ability to overcome. It is the latter judgmental assessment that is needed in describing a scenario with respect to one of our fundamental characteristics. The Delphi judgments that were rendered showed that there was good consensus among the participants, although one rating showed Korean terrain as very favorable to the U.S., higher than the majority. One rating showed SWA terrain as moderately favorable to the U.S., lower than the majority. In general, the participants rated none of the terrain in the scenarios as "very difficult" for the U.S. forces.

Weather. The range of weather typical to the climate of a theater of conflict has a major effect on ground combat, maneuver, resupply, and air operations. Assessments of the effects of weather in a scenario must include any relative advantage the U.S. or an adversary enjoys during weather extremes that can be experienced in the region. It also must consider whether or not the adversary is likely to have the initiative (enabling him to choose advantageous weather to

[7]Davis and Finch, 1993.

conduct his operations). If the adversary has no advantage or can not usefully choose to conduct operations in weather unfavorable to the U.S., the relative importance of this characteristic would be lower.

There is very good consensus among the Delphi experts with regard to weather. Although these scenarios incorporate vastly different weather, there is no case where the Delphi experts rated the weather as very difficult for the U.S. These scores may very well be due to the efforts put forth over recent years by the U.S. Army and the U.S. Air Force to develop all-weather capabilities.

Deployment Distance. This characteristic assesses the distance that the U.S. forces planned for use in the scenario would have to travel in order to reach the theater of operations. This includes movement within the U.S. as well as movement overseas, and should consider the difficulties associated with changing modes of transport along with capacity or other mode-unique limitations.

There is less consensus among the Delphi experts on this characteristic compared with the consensus concerning weather and terrain. The disagreements do not come from the rather deterministic assessment of the distance (for example, to Korea), but rather from the U.S. ability to cope with that distance, particularly when the deployment involves the need to move heavy divisions across the U.S. to depart from West Coast ports. In short, there is disagreement about the capability of U.S. sealift and airlift, particularly when multi-mode deployments are envisioned. These scenario scores cover the characteristic space with regard to deployment distance and emphasize the importance of this characteristic in scenario selection.

Strategic Choke Points. This characteristic describes the implications for the deployment of U.S. forces if their sea lanes to the conflict area must pass through a strategic choke point such as the Panama or Suez canals, the Strait of Hormuz, or the Bosporus. Air lines of deployment are affected by this characteristic in a similar manner. The obvious concern is the potential for U.S. forces to be subject to interdiction or delay in the choke points. (We have generally assumed that both means of deployment are necessary for an effective and timely insertion of forces, and that they are poor substitutes for one another.)

There is good consensus concerning the evaluations of how each scenario rates with respect to the problems presented by the characteristic "strategic choke points." The disagreements that do exist do not come from the assessment of the existence of the choke point, but rather from the U.S. ability to cope with the opponent's attempts to interdict the choke point. As with deployment distance, these scenario characteristic scores emphasize the importance of this characteristic in scenario selection.

Characteristics That Have the Potential to Change

A second class of characteristics can be changed over a sufficient period of time given enough resources and commitment from the involved governments. These characteristics include air infrastructure, ground infrastructure, operations with a coalition, importance of U.S. "heavy forces," importance of U.S. "light forces," air threat sophistication, ground threat sophistication, and threat size. As each characteristic is discussed in turn, the reader can speculate as to how an adversary could go about changing a characteristic.

Air Infrastructure. This characteristic describes how much infrastructure would be required for the U.S. air forces involved in the scenario to function effectively, and how much is available. If not much were required, then a scenario would rate high on this characteristic. If a great deal of infrastructure is required, but a lot is available, the rating would also be high, because these

situations are favorable to the U.S. This characteristic regards the infrastructure components that directly support air operations: airfields and the air traffic control system; to a lesser extent this includes the rail and road systems, as well as the power generation/distribution system (to the degree that these systems support air base operations). This characteristic (as well as the ground infrastructure characteristic) is important to analyze explicitly because we have grown accustomed to taking for granted the air (and ground) infrastructure that exists to support our forces in a NATO context. Most parts of the world will not support our sophisticated air and ground forces as well as Western Europe, so it is important when attempting to compute conflict outcome to understand how the performance of our forces will be degraded by the available infrastructure.

There is very good consensus among the Delphi experts on this characteristic for the Korean, Cuban, and SWA scenarios. The disagreements that do exist do not come from the assessment of the existence of the air infrastructures in Poland and Romania, but rather from the uncertainty about the implications for the air war if Russia enters the conflict.

However, discussion among the Delphi participants indicated that the capabilities of the U.S., as the world's only remaining superpower, could render some problems as almost always tractable. For this characteristic, the view was that some combination of long-range operations, carrier basing, and reliance on neighboring allies' air infrastructure would provide "work-arounds" adequate to prevent the problems presented by a limited air infrastructure from becoming critical. This suggests that the air infrastructure available in a scenario is not a particularly important characteristic when choosing situations to evaluate close support system characteristics.

Ground Infrastructure. This characteristic describes how dependent the U.S. ground forces are on infrastructure, and how capable the available infrastructure is. Again, if not much is required, or if a lot is required, but a lot is available, a scenario would rate high according to this characteristic, because the situations represent an advantage for the U.S. The characteristic considers the infrastructure components that are necessary to support the large force size typically associated with the employment of ground forces in a broad context: rail systems, roads, power generation and distribution, and seaports and receiving facilities.

There is generally good consensus among the Delphi experts with regard to this characteristic. The disagreements that do exist do not come from the assessment of the existing ground infrastructure in Poland, but rather from the uncertainty about the requirements for ground infrastructure if Russia should enter the conflict. The Delphi discussions noted that the U.S. is the only remaining superpower in the world and that the Gulf War was a dramatic example of the U.S. force's ability to deal with the problems presented by a limited ground infrastructure. This suggests that the ground infrastructure available in a scenario is not a critical limitation on U.S. and allied capabilities.

Operations with a Coalition. This characteristic measures whether a coalition would benefit the U.S. politically at home or in the region, and how hard it would be to maintain the coalition and conduct military operations within the constraints imposed by the coalition.

There is fair consensus concerning the evaluations of how each scenario rates with respect to the problems presented by the characteristic "operations with a coalition." The disagreements that do exist reflect the uncertainty about whether NATO will enter the scenario in support of the U.S. The views of the Delphi experts reflect the fact that the U.S. is the only remaining superpower in the world, and they believe that while a "go it alone" approach is awkward, U.S. forces can overwhelm any potential adversary without a coalition if necessary. This suggests that the

availability of a coalition in a scenario is not a particularly important characteristic when choosing situations to evaluate close support system characteristics.

Need for/Importance of U.S. "Heavy" Forces. Armor and mechanized infantry forces constitute the "heavy" forces and may be the most appropriate forces for a scenario depending on the terrain and the forces of the adversary. This characteristic was addressed to deal with the views of the constituency in the Army that feels that heavy forces can be dominant in most conflicts.

There is fair consensus among the Delphi participants in the belief that while heavy forces are important, the combination of U.S. light forces and U.S. air forces could overwhelm any potential adversary without heavy forces if necessary. This suggests that the availability of heavy forces in a scenario is not a particularly important characteristic when choosing situations to evaluate close support system characteristics.

Need for/Importance of U.S. "Light" Forces. Air assault, airborne, and light infantry forces may be the most appropriate force for some scenarios (or phases of a scenario) due to the nature of the terrain or the rapid deployment characteristics of these forces. The evaluations of how each scenario rates with respect to the problems presented by this characteristic were carried out to deal with the views of the constituency in the Army that feels that light forces can be adequate for most conflicts.

There is less consensus among the Delphi participants on this characteristic than on the need for heavy forces. In SWA, higher scores reflect the fact that light forces will be required to slow down the advance of the adversary in the early days of the scenario. The higher scores reflect the fact that as time progresses, heavy forces will be required to force the adversary out of territory that was initially occupied and to destroy the adversary's ability to support offensive actions. Additional scenarios involving heavy jungle terrain or peacekeeping deployments to Africa or the Caribbean presumably would elicit higher scores for the importance of light forces.

The next three characteristics deal with the quality and quantity of the threat. We have separated the quality (sophistication) and quantity (size) in these characterizations of scenarios, recognizing that these characteristics may prove difficult to evaluate separately. (Regard the case of an adversary with a small number of highly sophisticated systems that the U.S. must carefully handle until they are eliminated—which it eventually does very well. While this might be viewed as a sophisticated threat that poses problems for the U.S. and warrants a low score, the sophistication is, in the end, limited by the small numbers involved.)

Air Threat Sophistication/Adroitness. This characteristic describes how appropriate the level of technological sophistication is for the adversary's purposes in each scenario. It assesses the adroitness with which the adversary employs the technology that is available to him. If the two match well to the disadvantage of the U.S. forces, a scenario's score on this characteristic would be lower. We have included air defenses and long-range surface attack missile systems in the air threat.

There is good consensus among the Delphi participants. The disagreements that do exist do not come from the assessment of the air threat sophistication/adroitness in Poland and Romania, but rather from the uncertainty about the implications if Russia should enter the scenario. It is not surprising that these scenarios do not cover the space very well. The U.S. is the only remaining superpower in the world, and the Gulf War was a dramatic example of the U.S. Air Force's ability to dominate an opposing air threat. High scores are not so much a measure of low "air threat sophistication/adroitness" as they are a reflection of the belief that the U.S. air forces can overwhelm any existing air threat worldwide. This suggests that the "air threat

sophistication/adroitness" in a scenario is not a particularly important characteristic for scenario selection.

Ground Threat Sophistication/Adroitness. This characteristic describes the adversary's ground forces in the same manner as was done for the air threat. For example, if the terrain is very rugged and has substantial cover (as in jungle terrain), the current state of military technology is such that infantry is still the most appropriate type of force to be used. The level of technological sophistication of infantry forces is not high in comparison to many other domains of warfare today, yet this level of sophistication would be highly appropriate if an adversary were adroit enough to use it in such terrain. Similarly, technically sophisticated weapons systems in the hands of an adversary not adroit enough to use them to their full advantage might pose less of a problem for the U.S. than an adversary equipped with more usable technology.

There is good consensus among the Delphi participants. The scores for Cuba do not reflect sophistication in the technological sense, but rather the belief that the Cuban troops may be effective fighters in the jungle, cane field, and village environments of this scenario. The scores for SWA reflect uncertainty about the quality of the equipment that Iraq would purchase to replace the equipment destroyed in the Gulf War. These low overall scores reflect the fact that the Delphi participants believe that the U.S. forces can overwhelm any potential adversary regardless of the sophistication of the ground threat. This suggests that the "ground threat sophistication/adroitness" in a scenario is not a particularly important characteristic for scenario selection.

Conventional Threat Size. This characteristic measures the consequences of the sheer size of the threat. If, as some have argued, the size of the adversaries in our scenarios is of little concern to the U.S. because of its qualitative advantage, then there should be little difference in this characteristic across the scenarios. The larger the size of the threat forces, the lower a scenario would fall on the scale for this characteristic, since this would represent a disadvantage for the U.S.

There is good consensus among the Delphi participants, but the scores indicate that the U.S. may experience a problem. These low overall scores reflect the fact that the U.S. may be facing the threat in the close proximity of the adversary's country, and could face essentially his entire military infrastructure. This change is a logical consequence of the shift in strategic emphasis from central Europe (where we had substantial in-place forces) to potentially worldwide involvement.

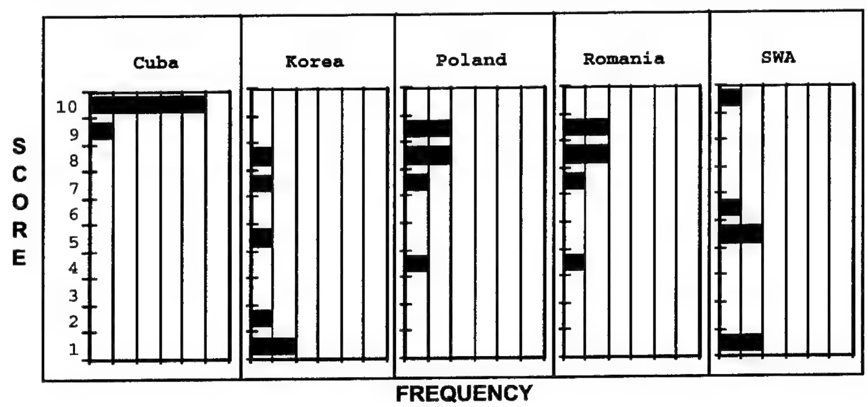
Characteristics That Are Likely to Be Variables

Characteristics in this class are likely to be variable because they depend on decisions made by the adversaries in the conflict. Longer-term decisions to develop nuclear, biological, and chemical weapons and shorter-term decisions to employ such weapons are examples of such scenario characteristics because they depend on such a complex set of influences that they are unlikely to be predictable.

Time Available to Respond. As a practical matter, is the time available to the U.S. sufficient to allow the U.S. to respond adequately to the problem? If the time available is likely to be adequate to emplace the needed forces in the theater, a scenario rates high on this characteristic. Similarly, if adequate U.S. forces were already in place in the region, a scenario would rate more highly as to this characteristic than would scenarios that required the deployment of initial response forces.

The evaluations of how each scenario rates with respect to the problems presented by the characteristic "time available to respond" show good consensus among the Delphi participants. These scenarios do cover the space well since the measures of central tendencies vary from 10.0 to 1.5. This scoring behavior is a strong confirmation of the fact that the "time available to respond" is a very important determinant of how many and what type of U.S. forces can be employed in the conflict. This suggests that the "time available to respond" in a scenario is a very important characteristic for scenario selection, particularly because it is a decision that rests almost entirely with the aggressor.

Nuclear Weapons. If the enemy has nuclear weapons available and is likely to use them, and the resulting influence on U.S. initiatives would be pronounced, a scenario would rate low on the scale for this characteristic. The evaluations of how each scenario rates with respect to the problems presented by the characteristic "nuclear weapons" is shown in Figure A.1. There is very good consensus for the Cuban scenario based on the belief that Cuba will not have nuclear weapons available. There is uncertainty about the potential behavior of the Former Soviet Republic in the Poland and Romania scenario. However, there is wide uncertainty reflected in the Korea and SWA scenarios.



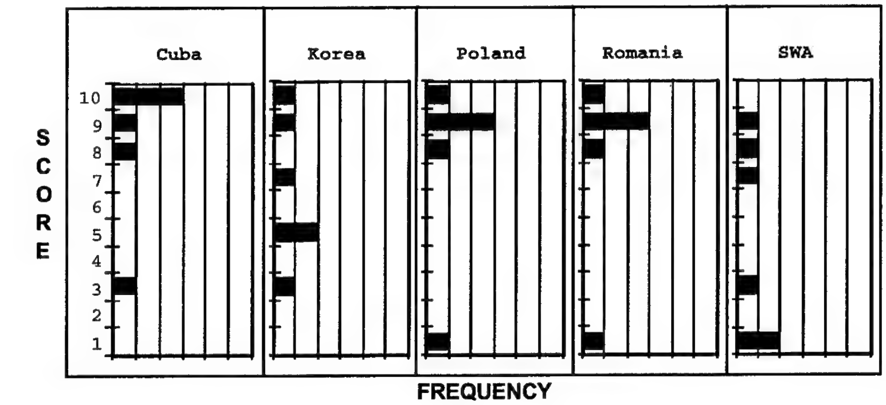
	Cuba	Korea	Poland	Romania	SWA
MEDIAN	10.00	3.50	8.00	8.00	5.00
MEAN	9.83	4.00	7.50	7.50	4.67
STD DEV	0.41	3.10	1.87	1.87	3.39

Figure A.1—How Each Scenario Rates as to Nuclear Weapons

Each of these totalitarian states is known to have sought to build a nuclear capability. Each is ruled by a despotic leader, one of whom has used chemical weapons against an adversary as well as a segment of his own population. The lack of consensus invalidates the notion of "covering the space." Further, it suggests that consensus might not be possible and that, where experts have such strongly held diverging views, the influence of the characteristics involved might be viewed as "unknowable" rather than "uncertain." This suggests that the use of nuclear weapons in a scenario is a very important characteristic for scenario selection, particularly because it is a decision that rests almost entirely with the aggressor.

Biological Weapons. The characterization of a scenario with respect to biological weapons is governed by the same considerations used for nuclear weapons. The evaluation of how each scenario rates with respect to the problems presented by the characteristic "biological weapons" is shown in Figure A.2. There is no consensus view about the use of biological weapons in these

scenarios. This is due to the ease of obtaining these weapons and the fact that, unlike nuclear weapons, they do not destroy infrastructure. There is uncertainty about the potential behavior of the Former Soviet Republic in the Poland and Romania scenarios, but one Delphi participant in each case drives the spread of the judgments. However, there is wide deviation in the Korea and SWA scenarios due to the same conditions discussed for nuclear weapons.

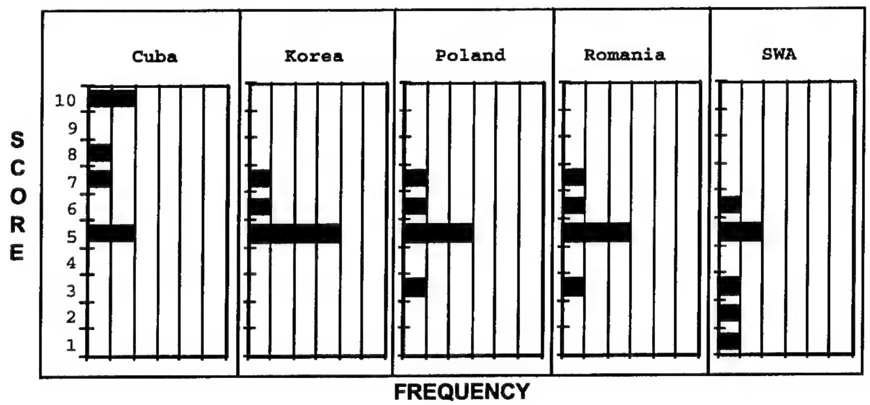


	Cuba	Korea	Poland	Romania	SWA
MEDIAN	9.50	6.00	9.00	9.00	5.00
MEAN	8.33	6.50	7.67	7.67	4.83
STD DEV	2.73	2.66	3.33	3.33	3.60

Figure A.2—How Each Scenario Rates as to Biological Weapons

Once again the scoring suggests that consensus might not be possible and that, where experts have strongly held diverging views, the influence of the characteristics involved might be viewed as "unknowable" rather than "uncertain." Clearly the use of biological weapons in a scenario is a very important characteristic for scenario selection, particularly because it is a decision that rests almost entirely with the aggressor.

Chemical Weapons. Scoring for chemical weapons is governed by the same considerations used for nuclear weapons. The evaluations of how each scenario rates with respect to the problems presented by the characteristic "chemical weapons" is shown in Figure A.3. There is no consensus view about the use of chemical weapons in these scenarios. This is partially due to the ease of obtaining these weapons and the fact that, unlike nuclear weapons, they do not destroy infrastructure. There is uncertainty about the potential behavior of Cuba and the Former Soviet Republic with respect to the use of chemical weapons. Also, there is wide deviation in the Korea and SWA scenarios. Each of these totalitarian states is believed to have a chemical weapon capability, and, as previously discussed for nuclear and biological weapons, each of their leaderships is unstable.



	Cuba	Korea	Poland	Romania	SWA
MEDIAN	7.50	5.00	5.00	5.00	4.00
MEAN	7.50	5.50	5.17	5.17	3.67
STD DEV	2.26	0.84	1.33	1.33	1.97

Figure A.3—How Each Scenario Rates as to Chemical Weapons

This uncertainty suggests that consensus might not be possible and that, where experts have strongly held diverging views, the influence of the characteristics involved might be viewed as "unknowable" rather than "uncertain." Once again this suggests that the use of chemical weapons in a scenario is a very important characteristic for scenario selection, particularly because it is a decision that rests almost entirely with the aggressor.

The Major Contribution of the Delphi Analysis: Leading Edge Problems

Figure A.4 is a "stoplight chart" that shows how each scenario was rated on the fundamental characteristics and provides a sense of how the scenarios cover the scenario characteristic space. A standard deviation greater than 2.0 was judged not to have converged and was not assigned a color. A mean lying between 1 and 3.3 was assigned a color code of red and indicates a major problem for the U.S. A mean greater than 3.3 and less than 6.7 was assigned amber, indicating a moderate problem for the U.S. A mean between 6.7 and 10 was assigned light blue, indicating only minor problems. Light gray indicates that the data would not support an assessment (there was no consensus opinion by the participants). A number of interesting trends emerge: "air threat sophistication" is light gray across the board, suggesting that the participants view no air threat as being sufficiently sophisticated to cause the U.S. any difficulties. Similarly, the dark gray rating across the board for "ground threat sophistication" suggests that the participants view no ground threat as being sufficiently sophisticated to cause the U.S. any serious difficulties.

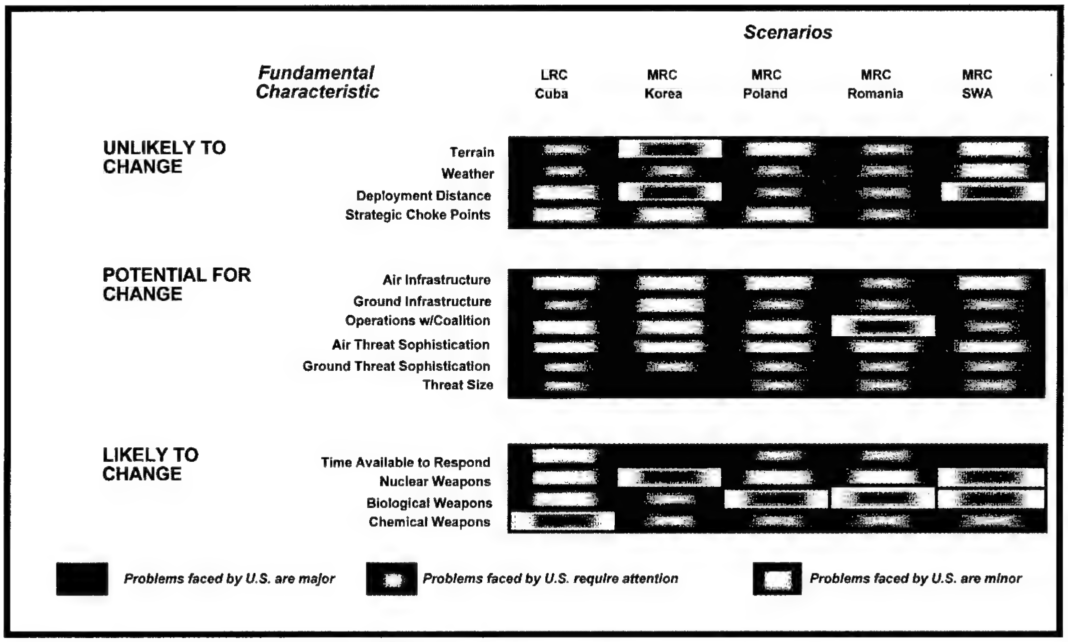


Figure A.4—Summary of Delphi Assessments

Only three characteristics were scored in the black: "strategic choke points" for the SWA scenario, "threat size" for the Korean scenarios, and "time available to respond" for the Korean and SWA scenarios. In 15 percent of the cells, the participants were judged not to have reached consensus on the scores.

The scenario analysis that we performed confirmed the finding from our independent analysis of the planning documents and other guidance used by DoD officials that providing support to allied forces would be a pervasive dimension of future U.S. military involvement. In fact, Figure A.4 shows that our defense experts believed that, in general, the requirement for U.S. forces to operate in support of allies would present "minor problems," at worst, problems that would require "some attention." The impact of this analysis on the remainder of the study was that in developing the combat vignettes that were used for detailed simulation-based analysis, a third of them involved supporting allies. In those vignettes, we investigated in detail the ways in which close support assets could support allies.

The historical analysis that we performed on the actual employment of U.S. military forces over the past 30 years shows a preponderance of evidence to support the growing importance of U.S. light forces in U.S. national security policy. The Delphi-based scenario analysis that we performed generally supported the concept of the use of these forces. On average, they were judged to be more rather than less important to the outcome, and, in at least one case, one might argue that their involvement was considered crucial. One problem that became apparent during the analysis after the Delphi experiment was concluded was that our Delphi experiment should have treated more explicitly the time phasing of the U.S. response to the threat posed by the scenario opposition. Due to the nature and the preconflict positioning of the Army and Marine light forces, they generally will be the first forces that are deployed to the region of concern. Whether or not they will be engaged before or after the closure of heavy forces is a somewhat complex decision on the part of the leadership of the contending powers. It is interesting to speculate on what the outcome would have been had the leadership of Iraq decided to engage the 82nd Airborne Division when it was virtually the only U.S. combat force on the ground in the region. Given the outcome of what did occur, a future despot must recognize that should he

practice aggression in a region, he has to be prepared to engage U.S. light forces, supported initially by land- and sea-based fixed-wing aircraft.

An interesting perception pervaded the discussions that occurred during the Delphi experiment and manifested itself in the results. This view could be summarized as: "When the United States employs the full range of its military forces it will be successful." For example, it was clear that our experts believed that U.S. airpower would dominate any adversary in the world. It was their general belief that the U.S. could operate successfully with its allies and that U.S. light infantry forces had been adequate to their tasking over the years. Given this, the problem that remained was to try to understand the isolated places where our experts thought there could be problems upon which we should focus the analysis.

As we previously stated, only four combinations of scenario and characteristic were thought to cause "major problems" for U.S. forces: strategic choke points for the SWA scenario, threat size for the Korean scenarios, and time available to respond for the Korean and SWA scenarios. We sought a common thread running through these combinations and came upon "leading edge problems." In each of these four combinations of scenario and scenario characteristic, it was a problem of the early inadequacies of the U.S. forces given the scenario setting. In fact, upon reflection, all but the most contrived situations have the potential for involving U.S. "leading edge" forces in combat, and often the decision is largely in the hands of the adversaries.

It is important to understand the distinction between "supporting light infantry" and "leading edge forces." *Leading edge forces* are not necessarily light in nature, but merely lacking in some dimension that impedes their effectiveness. The problem may be inadequate C4I, shortage of given equipment, or supply constraints.

The leading edge problems have many of the characteristics of the previously envisioned battle environment: U.S. forces are outnumbered and on the defense, and often the adversary consists of heavy armored forces. Some conditions have changed in the new defense environment, however. There is a greater priority placed on first managing attrition and then finding a way to operate effectively.

While the capabilities and limitations of early deploying U.S. forces have always been a concern, understanding leading edge problems (such as the limited firepower and tactical mobility of our most rapidly deployable forces) and finding solutions to these problems (which may include augmenting early forces with close support firepower) may be of even greater importance in a contingency environment than in the past. This may be particularly true in that it seems prudent to assume that future adversaries may have learned well from Saddam Hussein's mistakes in giving the U.S. the time to mass its combat power and build coalitions.

Additional Findings

In addition to arriving at the findings that have a direct impact on the question of what types of battle situations might critically rely on close support to ensure favorable battle outcomes, the study team developed an appreciation of what battle environments were overlooked in its initial selection of scenarios for the Delphi. These holes fell into two broad categories:

Large Light Force Contingency. The participants noted that the collection of scenarios used for the Delphi did not include a large light force conflict. Such a scenario might be cast as an extension of an existing scenario (the Iraqi army continues to offer resistance from bases in the swamp land surrounding the Tigris and Euphrates rivers upon defeat of their armored forces) or as a separate scenario (a conflict in Zaire or Peru, for example). A "jungle terrain" scenario could

provide the context for a "large light force contingency" and would provide the most demanding terrain environment for U.S. forces.

Peacekeeping/Peacemaking Contingency. The participants also observed that peacekeeping/peacemaking missions may have unique enough characteristics to warrant separate and specific inclusion. Some of the scenarios used in the Delphi (such as the conflict set in Romania) might also serve as a platform through which to examine peacekeeping/peacemaking issues. Somalia or Bosnia present themselves as candidates as well, but come with "baggage" that make them difficult to use in weapons systems analysis.

The development and analysis of additional theater-level scenarios was beyond the scope of the project; however, the remaining resources for this research did allow the study to capture many of the important aspects of the light infantry and peacekeeping scenarios developed at the tactical level for detailed analysis.

Other insights developed by the study team because of the structure and intensive nature of the Delphi discussions included several additional scenario characteristics that may be important in future assessments:

Constraints on U.S. Operations. Since U.S. forces have often had to operate under considerable political constraints (allowing the adversary sanctuaries, classes of targets that could not be attacked, etc.), some regard of these as fundamental characteristics of a scenario might be warranted.

U.S. Objectives. The range of different military objectives that the U.S. might pursue (defend territory; stabilize a regime; conduct offensive operations to eject an adversary, seize and hold territory, or destroy an enemy's forces) can result in substantially different conflicts. Some regard of these as fundamental characteristics of a scenario might be warranted.

These factors were taken into account in designing the peacekeeping scenario and its associated tactical-level vignettes. They particularly influenced the selection of success criteria and the types of U.S. forces involved in the battles.

Appendix B
RAND's Tactical Combat Simulation Environment

Seamless Model Interface (SEMINT)

The SEMINT modeling system developed at RAND integrates multiple simulation and support programs into one interconnected system. The component models have been developed by different services and analytic agencies, are written in different programming languages, and run on different hardware. In effect, SEMINT gives us the ability to improve any particular model's algorithms without modifying them. The system links the following simulations:

- JANUS, a ground combat model;
- RTAM, a target acquisition model;
- RJARS, a ground-to-air combat model;
- BLUE MAX (fixed wing) and CHAMP (helicopter) flight path models;
- MADAM, a smart munitions damage assessment model; and
- CAGIS, a cartographic analysis and geographic information system.

By connecting these models, we can conduct a JANUS battle simulation augmented by the specialized high-fidelity computations of other high-resolution models.

Components of the System

As currently configured, JANUS conducts the ground battle, calling on RTAM to provide more accurate calculation of detection probability on special low-observable vehicles. Should the conflict involve helicopter or fixed-wing operations, the flight path simulations (BLUE MAX and CHAMP) determine aircraft flight path dynamics based on engineering-level flight performance models for the type and model of aircraft specified. These are flown against the changing threat laydown that is provided by JANUS as the battle unfolds and are then passed to RJARS, which simulates the ground-based defense reaction against the aircraft. This high-resolution simulation includes detection, tracking, jamming, SAM operations, and suppression of enemy air defenses (SEAD) with anti-radiation missiles. CAGIS provides consistent geographic information to all the simulations, while SEMINT passes messages among the models as it maintains a Global Virtual Time to keep the models in synchronization.

JANUS, a high-resolution, stochastic, two-sided, interactive, computerized ground combat simulation, lies at the heart of this system of models. It is used for combat developments, doctrine analysis, tactics investigation, scenario development, field test simulation, and training. It models up to 1200 individual combat systems, including up to 100 indirect fire systems per side, moving, detecting, and shooting over a 60-kilometer-square, three-dimensional terrain representation (Defense Mapping Agency [DMA] DTED level II data).

Combat systems (e.g., tanks, infantrymen, helicopters) are defined by the quantified attributes of the real or notional systems being modeled (e.g., size, speed, sensor, armament, armor protection, thermal/optical contrast, and flyer-type for helicopters and fixed-wing aircraft). The vulnerability of systems is characterized by probability of hit, P(h), and probability of kill, P(k), data sets individually associated with weapon-versus-system pairs. Up to 250 systems, and 250 weapons, may be defined per side. Each system may be armed with up to 15 different weapons and may search and detect with two different sensors, employing the Night Vision Electro-Optics Laboratory (NVEOL) detection model. It also incorporates a Light-TACFIRE based command and control module capable of allocating supporting fires and providing target deconfliction.

The model's graphic display capability affords the analyst the ability to examine spatial-temporal behavior, thereby aiding the analytic process by directing focus to causal chains occurring during simulation. Further, the completeness of the output available to the analyst permits a detailed examination of the individual contributions attributable to each parameter change and aids in quantifying the contribution of synergy to combat outcomes.

Appendix C
Data for Systems, Units, and Vignettes

This appendix specifies the data and data sources for the close support systems, the military units, and the combat vignettes simulated in this analysis.

Escort of a Humanitarian Convoy

Location: Unspecified.
Terrain: Rolling hills; moderate foliage; extensive road network.
Weather: Good.
Time Frame: Present.
Unit Type:

BLUE/GREEN—Supply convoy (30 trucks) escorted by 10 HMMWVs armed with .50 caliber machine guns.

RED—Ambush patrol (long range) consisting of 24 personnel armed with medium-range anti-tank guided missiles and rocket-propelled grenades.

Mission/Posture:

BLUE/GREEN—Conduct humanitarian aid convoy operations.

RED—Prevent delivery of humanitarian aid; harass coalition forces.

Objective:

BLUE/GREEN—Maximize supplies delivered.

RED—Destroy supplies prior to delivery.
Data Sources: All data for close support systems examined in this vignette were provided in the JANUS Standard Data Base.

Defense of an Allied Enclave

Location: Unspecified.
Terrain: Urban environment surrounded by rough, cross-compartmented, moderately foliated terrain.
Weather: Good.
Time Frame: Present.
Unit Type:

BLUE/GREEN—One GREEN battalion of light, irregular infantry including 4 HMMWV-TOW IIB, 6 HMMWV-Scouts with .50 cal. MGs, 20 medium MGs, 30 Dragon launchers, and 30 light, anti-tank weapons (LAWs).

RED—Three battalions of tank-heavy mechanized forces including 50 T-72 main battle tanks (MBTs) and 40 BMP-2 infantry fighting vehicles (IFVs).

Mission/Posture:

BLUE/GREEN—Prepared defense.

RED—Deliberate attack.

Objective:

BLUE/GREEN—Defend city; maximize survivability; destroy RED force to the degree necessary to defeat the attack.

RED—Defeat BLUE/GREEN forces in detail.

Data Sources: All data for close support systems examined in this vignette were provided in the JANUS Standard Data Base with the following exceptions:
Sensor Fused Weapon—Official U.S. Air Force sources based on "Chicken Little" test results and modified by manufacturer data.
Internally generated RAND estimates based on SFW data.

Small Unit Infantry Assault

Location: Unspecified.
Terrain: Complex terrain amid open, flat area surrounded by hills with moderate foliage.
Weather: Poor.
Time Frame: Present.
Unit Type:

BLUE—Task-organized Special Operations Force team; 12 assault and 40 support and security.

RED—Security guard detail; guard force—32 light infantry; Immediate Reaction Force (IRM)—36 light infantry; Quick Reaction Force (QRF)—120 light infantry, five T-72 main battle tanks (MBTs), 15 armored personnel carriers (APCs).

Mission/Posture:

BLUE—Special item recovery.

RED—Compound defense.

Objective:

BLUE—Penetrate key building with sufficient survivability to secure special item.

RED—Prevent compound penetration.

Data Sources: All data for close support systems examined in this vignette were provided in the JANUS Standard Data Base with the following exceptions:
Man-portable EFOG-M—Internally generated RAND estimate based on EFOG-M data.
EFOG-M—MICOM/EFOG-M Program Office.

Small Unit Infantry Patrol

Location: Unspecified.
Terrain: Urban with multi-story buildings.
Weather: Good.
Time Frame: Present.
Unit Type:

BLUE—Platoon-size light infantry patrol: 25 riflemen, 5 grenadiers, 5 Javelin gunners, 5 medium machine gunners.

RED—An ambush force of 51 irregular infantrymen with individual and crew-served automatic weapons.

Mission/Posture:

BLUE—Forced march to base of operations after day-long patrol.

RED—Prepared ambush of BLUE patrol.

Objective:

BLUE—Maximize survivability of patrol.

RED—Maximize BLUE attrition.

Data Sources: All data for close support systems examined in this vignette were provided in the JANUS Standard Data Base with the following exception(s):
Mission flight profile for AC-130 gunship—Special Operations Command (SOCOM) J-6.
Laser-guided 105-mm high explosive projectile—SOCOM J-6.

Light Force Hasty Defense

Location: Latin America.
Terrain: Mixed topography ranging from heavily foliated, steep hills to large open plains with an extensive road network.
Weather: Good—90 percent day (better than 90 percent of all days in the region in one year).
Time Frame: Present.
Unit Type:

BLUE—Remnants of 82nd Airborne Division Ready Brigade (DRB): approximately two battalions.

RED—Two Soviet-style regiments: one tank and one motorized.

Mission/Posture:

BLUE—Hasty defense.

RED—Hasty attack.

Objective:

BLUE—Retain control of combat airstrip and nearby town until relieved by heavy forces.

RED—Seize control of combat airstrip by defeating BLUE in detail.

Data Sources: All data for close support systems examined in this vignette were provided in the JANUS Standard Data Base with the following exceptions:
Damocles—M-STAR Database.
SADARM—M-STAR Database verified by manufacturer's program personnel.
Sensor Fused Weapon— Official U.S. Air Force sources based on "Chicken Little" test results and modified by manufacturer data.

Light Force Prepared Defense

Location: Southwest Asia (SWA).
Terrain: Open desert characterized by long lines of sight, dry stream and river beds. Area also contains a critical road network.
Weather: Good—90 percent day (better than 90 percent of all days in the region in one year).
Time Frame: Present.
Unit Type:

BLUE—The 82nd Airborne Division Ready Brigade (DRB) equipped with 58 HMMWV-TOW IIB, 54 Javelins, 14 Armored Gun Systems (AGSs), and 5 AH-64D Apaches.

RED—Two tank and one motorized Republican Guard (Soviet-style) regiments that include approximately 12 battalions, 311 T-72S main battle tanks (MBTs), 200 BMP-2 armored fighting vehicles (AFVs).

Mission/Posture:

BLUE—Prepared defense.

RED—Deliberate attack.

Objective:

BLUE—Retain control of critical road network until relieved by heavy forces.

RED—Seize control of critical road network to be used as MSR by defeating BLUE force in detail on high ground providing over-watch for a critical intersection.

Data Sources: All data for close support systems examined in this vignette were provided in the JANUS Standard Data Base with the following exceptions:
Damocles—M-STAR Database.
SADARM—M-STAR Database verified by manufacturer's program personnel.

Armored Force Meeting Engagement

Location: Eastern Poland.
Terrain: Rolling hills with moderate foliage that is suited to armor operations.
Weather: Good—90 percent day (better than 90 percent of all days in the region in one year).
Time Frame: Present.
Unit Type:

BLUE—Heavy brigade with attached division cavalry. Force consists of 108 M-1A1 main battle tanks (MBTs), 138 infantry fighting vehicles (IFVs), 24 improved TOW vehicles (ITVs), 14 cavalry fighting vehicles (CFVs), 6 AH-64D Apaches, 24 FiSTVs.

RED—One Soviet-style mechanized regiment that includes 120 T-72S main battle tanks (MBTs), 58 BMP-2 armored fighting vehicles (AFVs), 10 BTR-60P armored personnel carriers (APCs), 6 HIND-E armored helicopters, 6 HAVOC attack helicopters, 24 SA-15/2S-6 air defense vehicles.

Mission/Posture:

BLUE—Movement-to-contact transitioning into a hasty attack.

RED—Movement-to-contact transitioning into a hasty defense.

Objective:

BLUE—Destroy RED incursion force prior to arrival of RED reinforcing heavy division.

RED—Withstand BLUE attack until reinforcing heavy division arrives.

Data Sources: All data for close support systems examined in this vignette were provided in the JANUS Standard Data Base with the following exceptions:
Damocles—M-STAR Database.
SADARM—M-STAR Database verified by manufacturer's program personnel.
EFOG-M—MICOM/EFOG-M Program Office.

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